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MENTAL GROWTH DURING THE FIRST THREE YEARS*

A DEVELOPMENTAL STUDY OF SIXTY-ONE CHILDREN BY REPEATED TESTS

From the Institute of Child Welfare,
University of California

By

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I

INTRODUCTION

Early trends in mental growth, such as may be observed in the maturing behavior of infants during the first two or three years of life, should be of considerable value in clarifying theories of intelligence. The mental behavior of infants, being genetically prior to, and less complex than, that of school-age children or adults, should throw light on the more fundamental mental processes. In addition, the rapid rate of maturation of all of the processes of growth—mental, anatomical, and physiological—makes possible comparisons between successive stages of growth in the same children within a relatively short time interval.

What infant behavior may we call "mental"? What specific behavior precedes later mental achievements? To what extent are these later achievements dependent on the earlier? Can we predict later development from early behavior? How do individual growth rates compare with the norm for a group of infants? To what extent are these rates affected by environmental conditions? These are a few of the questions for which we may find some, at least partial, answers by means of repeated observations of the same infants under similar test conditions.

Although infant behavior has received comparatively little scientific study in the past, a recognition of its significance has recently emerged, so that at present we have a fairly large field of information from which to start in the study of mental development.

The early biographical studies, such as those of Preyer (45), Shinn (48), Major (41), Moore (42), Sully (54), and Hall (26), have provided careful descriptions of the mental growth of single infants; such studies serve as useful sources of behavior items for which norms may be compiled on the basis of tests of a large number of cases. In the last few years the field of mental testing has been pushed further and further into the early ages until now there are several series of tests designed for infants during the first two years of life, as well as for children of nursery-school age.

The first practical tests of intelligence, Binet's (7), included three or four items which are applicable to children under one year, but they were not given any very exact age placement. Kuhlmann (37), in his revision of the Binet tests (1922), extended his standardization down to three months, including items for scoring at the ages 3, 6, 9, 12, 18, and 24 months. Heubner (31), in 1918, in a discussion of mental development of infants, gives a brief outline of the achievements to be expected at two weeks and at 1, 2, 3, 6, 9, 12, 18, 21, 24, 30, and 36 months; usually no more than two or three tests are supplied for each level. A much more complete test for the first three years, with definite age placements but with no statements concerning the method of standardization, was published by Schwab (46) in 1925. In the same year Gesell (18) published his tests, to which he gave age evaluations on the basis of the performances of "several hundred children," five years and under, in a controlled test situation. He, however, felt that an exact age placement of the items was not justified and, instead, indicated the difficulty of performance of a test at any given age by letter ratings. This method, although it set forth the rapid growth changes and illustrated characteristic infant behavior, leaves each child's developmental score always an indefinite clinical estimate. In 1928 Hetzer and Wolf (30) published a series of "Babytests," giving monthly norms through 11 months for infants' performances, based on 24-hour observations of infants in Vienna. A later, slightly revised edition of these tests is given by Charlotte Bühler (10). Recently a group of tests for the second year has been added to this series by Hetzer and Koller (29).

Linfert and Hierholzer (39) have developed a point scale for infants during the first year. This scale is based on the Gesell tests and is divided into two series, one for each half year. It has been standardized on 300 infants, 50 at each of the ages, 1, 2, 4, 6, 9, and 12 months. The total point scores on these tests show a linear increase with age and an average reliability, by the split-half method, corrected by the Spearman-Brown formula, of .81. Hallowell (27) has standardized a group of tests beginning with one year and extending up to four years.

None of these test groups seems, in itself, to be entirely satisfactory for the first two-year span. In several cases, as has been indicated, the sample on which the age placements were made was very small, or else was not described at all. In several of the studies, too, the sample was selected and unrepresentative because of the greater ease of securing institution cases for observation. Other studies fail to give exact age placements or methods for determining relative performance in the tests. Many of the descriptions of procedure are too incomplete to assure duplication of the test situation or standard of scoring by other examiners.

A number of recent studies have been made on specific behavior patterns in infants, often with a large sample of children observed. In several cases developmental norms for the observed responses are given and are of such a nature as to be of value in a test of mental development. Of these studies, we may cite Jones (36), Lippman (40), Sherman and Sherman (47), and Blanton (8). There are, of course, many other recent studies of infant behavior which have a more or less direct bearing on the problem of mental growth in infants.

The tests for children in the later preschool years have been recently summarized by Stutsman (53) and by Pintner (44) and, perhaps, need no further description here. As this brief summary shows, we now have available sufficient norms of infant behavior to make possible comparative studies of mental growth and development and to determine more exactly the behavioral items which are significant as criteria of development.

Observations of infants provide evidence for a rapid growth in function as well as in structure during the first year. Early differentiations in maturity of response are based on simple sensory acuity and sensorimotor coordinations. We think of these as being allied to mental rather than merely to physical development. It therefore seems possible that individual differences in these types of infant behavior may be accepted as differences in intellectual ability which are similar to those observed at later ages. If, then, these differences can be measured reliably, we may hope that such measurements may be predictive of mental differences at a later age. If we can predict twelve-year intelligence with fair success at six years, perhaps we may hope equally well to predict six-year intelligence at six months.

Infant intelligence tests have been devised and standardized on the assumptions that maturation in sensorimotor functions and simple adaptations *are* intellectual and should be predictive of later intellectual performances. However, it does not necessarily follow that individuals whose sensory acuity is great and whose simple coordinations are perfected more rapidly will eventually be able to respond more adequately to complex situations. In adults, simple sensory tests have only very low correlations with intelligence. It may well be true that the relationship in infants is no greater, even though, developmentally, the simple forms of behavior appear first and are components of the more complex intellectual responses which develop later.

In cases of definite handicap in sensorimotor development we need not be surprised to find retardation in associated intellectual functions—as among neurological cases, or among individuals suffering from sensory deprivation. But when, among normal infants, a temporary delay occurs in sensorimotor maturation, this need not result in any marked effects upon subsequent intellectual growth.

We must bear in mind the possibility that behavioral development during the first year may, within rather wide normal limits, give little indication of later intelligence. Intelligence may involve characteristically "higher" functions which have very little representation in the infant's repertoire. It may be as difficult (outside of pathological deviations) to predict intelligence in infancy as it is to predict vocational aptitude or artistic genius in infancy.

The measurement of "intelligence" or "mental maturity" in infants depends upon techniques and instruments of measurement radically different from the now familiar ones used in obtaining intelligence scores for school children and adults. The entire maturation process is so rapid during the early years that there are, in fact, several distinct types of test situations encountered during the first three-year period. Some of these differences may be found in the nature of the test items themselves; others are due to changing attitudes in the child as he grows up. The month-old baby lies on his back in a crib and is active or suddenly quiet in response to touches, sounds, and sights. At six months, he can be tested in a number of definitely "adaptive" activities; he is very responsive to social stimuli; he is just beginning to sit alone and can be tested while sitting propped up before a table. Shortly after this level is reached, a new element enters into the testing situation which causes great difficulties in testing children who are brought in only at intervals for a short examination; at this stage they become afraid of strange or unusual persons and places. Their movements, and especially their vocalizations, are inhibited to such an extent that adequate scores of their ability sometimes cannot be obtained. They gradually get over this, but from 18 months on, for a year or more, they usually develop, in varying degrees, what has been called "negativism." At this stage a child may, as if on principle, refuse to do whatever is asked of him. No matter how interesting one makes a test, there will always be some children who refuse to attempt it. And many will inhibit some or all verbal responses which may be called for.

It is only after this phase is outgrown that one can achieve a test situation comparable to that which has usually been considered necessary in administering mental tests, that is, a desire on the part of the child to succeed in the task set for him, a directed effort to do his best, and full cooperation with the tester. Before this time, such effort can be secured only if the test itself elicits it; and no matter what the test, a child *may* not become interested, or if he does, he may expend his effort in a direction which was not intended and so fail to indicate whether or not he could have scored. For example, a child may insist on building houses with the formboard blocks instead of fitting them in the forms; or he may start a game of throwing the cubes to the floor instead of attempting to build with them.

With these individual variations in attitude, one can hardly expect to get completely accurate scores of ability. However, repeated tests of the same children at short intervals should make possible fairly reliable estimates of their test abilities and of growth trends of the group. A comparison of the early with the later scores of these same children may indicate to what extent the tests at various levels are measuring the same or comparable things.

The present study, carried on at the Institute of Child Welfare, has made such a comparison possible over the first three years of life—the period in which the most rapid growth occurs, and hence the one in which the most radical variations might be expected if they are to be found at all.

II

DATA COLLECTION

A. SAMPLE

Although some attempt was made to secure a sample which would be representative of the white, English-speaking population of Berkeley, several limitations necessary to the purposes of the study caused the selection of a group in some respects atypical. Only babies born in hospitals were included;[1] the two hospitals from which they were recruited represent a fairly wide socio-economic range, one of them, a county hospital, taking charity cases, the other drawing its patients from the middle and upper classes. From these two hospitals were enrolled normal, full-term infants whose mothers were cooperative and willing to make the necessary monthly visits to the Institute.

Of the 75 mothers interviewed (between September 27, 1928, and May 15, 1929), 59 who were cooperative and also met the other requirements were included in the study. As there were two pairs of twins, the results obtained are based on the data from 61 infants, 31 males and 30 females. All of these children came into the Institute of Child Welfare for at least six examinations. By the end of the first year, four had dropped out, leaving 57 still enrolled; by the end of the second year there were 53; and by the end of the third year 49 of the original 61 children were coming in for the tests.[2] A few children missed one or more examinations due to illness or visits out of town. Since the absences were fairly evenly distributed throughout the year, the smallest number of cases tested at any one age level during the first year was 52, with an average of 55.5; during the second year the minimum number was 45, with an average of 48; and during the third year the minimum was 45, average 47.25. In all, 1142 tests were made in the three-year period. Although the sample is not identical at every age level, it is very highly similar throughout, and any sampling selection may be considered practically constant at all ages. A cursory survey of the 12 cases which dropped gives no evidence of any selective factors in regard to family status which might have caused their withdrawal.[3]

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[1] Approximately 92% of Berkeley children are born in hospitals.

A comparison of the socio-economic status of the families of these children with the sampling of 405 Berkeley families obtained in the Berkeley Survey of the Institute of Child Welfare (60) has served to show in what ways the group under present consideration is representative. This comparison has shown that certain characteristics of the family background and environment are distributed in the same way for the children of the Intensive Growth Study (as the present investigation has been called) as for the population of all young children in Berkeley. These characteristics are sex of the infant being studied in the survey, sex of its siblings, number and age of the siblings, length of time the family has lived in Berkeley, age of parents at the time the survey infants were born, place of marriage, and age at marriage. There are, on the other hand, three characteristics in which the Intensive Growth Study group is, on the average, definitely superior; these are parents' education, occupation, and income. The mean educational level achieved by the fathers, in terms of years of schooling, was 13.8 years (Table 1), with a standard deviation of 3.6. The mean of the mothers was 13.1, S.D. 3.1. For the mid-parent scores, the mean is 13.4 year, S.D. 3.4. Only one father and one mother in the Intensive Study group had less than eighth-grade education. The Berkeley Survey means, as is shown in Table 1, are consistently lower than those for the Intensive Growth Study group, though higher than would be found in the average U. S. city of similar size.

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[2] Of the 12 dropped out, 9 moved out of town, 1 died through accident, while in two cases the mother, feeling the visits required too much of her time, refused to cooperate further.

[3] The educational distribution of the fathers of the remaining 47 families is practically identical with that of the original 59.

The occupations of the fathers have been classified,

TABLE 1

EDUCATIONAL LEVEL OF FATHERS AND MOTHERS OF INTENSIVE GROWTH STUDY COMPARED WITH BERKELEY SURVEY

	Fathers	Mothers	Mid-parent
	Intensive Growth Study		
Mean years schooling	13.8	13.1	13.4
Standard deviation	3.6	3.1	3.4
	Berkeley Survey		
Mean years schooling	11.4	10.9	
Standard deviation	4.1	3.6	
	Berkeley Survey (education in U. S.)		
Mean years schooling	12.2	11.6	
Standard deviation	3.6	3.2	

TABLE 2

OCCUPATIONAL CLASSIFICATION OF FATHERS

Description	Intensive No.	Berkeley No.	Intensive %	Berkeley %
Professional and executive	18	91	30.5	22.5
"White collar"	18	150	30.5	37.0
Skilled labor	7	83	11.8	20.5
Semi-skilled labor	3	46	5.1	11.4
Unskilled labor	3	21	5.1	5.2
Students	6	13	10.2	3.2
Retired	1	1	1.7	.2

in accordance with the procedure used in the Berkeley Survey, into five main groups, shown in Table 2. Both surveys show an equal predominance of II, white-collar occupations (37.3% Intensive, 39.0% Berkeley), but they differ decidedly in the other occupational groups, almost as many fathers of the Intensive Study group (30.5%) being in Group I as in Group II, while a smaller proportion, 22.5%, of the Berkeley fathers fall into this top class. Outside of the five classes of occupations listed above, 10.5% of the Intensive Study group were students, as compared with 3.2% of the Berkeley group. In the skilled, semi-skilled, and unskilled labor groups, correspondingly, there are comparatively few cases among the Intensive Study fathers.

If the annual incomes are grouped in one-thousand-dollar intervals, the lowest including all incomes under $1000, we find in both groups a definitely skewed distribution with most of the incomes below $4000 (Table 3). The Intensive Study group averages higher, with a mean annual income of $2844.61, while the Berkeley Survey mean is $2544.86.

TABLE 3

ANNUAL INCOME OF INTENSIVE GROWTH STUDY FAMILIES COMPARED WITH BERKELEY SURVEY

Annual Income	Intensive No.	Berkeley No.	Intensive %*	Berkeley %
Total	59	376	100.0	100.0
None (dependents)	4	—	—	—
0- 999	3	10	5.6	2.7
1- 1999	10	154	18.5	41.0
2- 2999	15	97	27.8	25.8
3- 3999	15	58	27.8	15.4
4- 4999	3	27	5.6	7.2
5- 5999	2	16	3.7	4.3
6- 6999	2	5	3.7	1.3
7- 7999	3	3	5.6	.8
8- 8999		2		.5
9- 9999				
10-10999	1	2	1.8	.5
11-11999		1		.3
20-20999		1		.3
Incomplete information	1			
Mean	$2844.61	$2544.86		
Median	2650.00	2020.00		

*Percentages on Intensive Growth Study computed on 54 cases, omitting dependents and incomplete information.

The education, occupation, and income of the Intensive Growth Study are positively related, as is seen from their intercorrelations (excluding the 8 students). The years of education of the fathers correlate with their total annual income .69.[4] Occupational ratings (on a rating scale of twelve)[5] correlate with education of the fathers .78, and with their annual income .67. These three interrelated, objective measures in which this group differs from the Berkeley population probably represent the same selective factors. They indicate that the parents who are sufficiently interested to enter into a study such as this are more likely to be above the average in socio-economic ratings. And it is clear that, as a group, the infants we are studying have a superior socio-economic background to that which would be found in an unselected population. However, there is a fairly wide range in all three of the characteristics in which the Intensive Study shows a selective difference from the Berkeley population, and no class is entirely unrepresented.

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[4] Correlations with income have been computed with the income groups based on an arithmetic-logarithmic scale, in order to obtain a straight regression line.

[5] This was an extension (made by the writer) of the five-point Berkeley Survey scale given above.

B. THE EXPERIMENTAL SITUATION

The mental tests are only part of a program calling for the cumulative study, over a period of several years, of reflex, physical, motor, bodily, and mental growth. Each of these variables was tested at every visit, and the developmental trends of the measures other than mental, with their interrelations, will be considered separately in other studies. The infants were first observed in the hospital within three days after birth.[6] At this time an appointment was made with the mother for the first visit to the Institute, one month from the date of birth. Age was reckoned by the usual solar month, and, since emphasis in this study was placed on the growth of the *same* children, in order to have as few absences as possible, a leeway of four days before or after the birthday was allowed.[7] Every effort was made, however, to keep the visit on the birth date, so that the wider variations were comparatively rare.

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[6] The hospital observations and interviews were made by Dr. Lotta V. Wolff.

The infants were examined with the mother present, unless for some reason she wished to send the child without her. This procedure had the advantage of gaining better cooperation from the mother, and of giving an opportunity to take notes on the mother's attitude toward, and treatment of, her child. Moreover, at the age when the strangeness of the testing situation became disturbing to the children (4), the mother's presence calmed and reassured timid infants, so that they were more easily reconciled to the approach and handling of the examiner. On the other hand, of course, some anxious mothers were inclined to interfere with the experimental procedure at times, and a careless mother occasionally distracted her child from a task which had been set for him, thus spoiling his chance to make the best possible score. On the whole, however, it was felt that the advantages of the mothers' presence outweighed the disadvantages, until the children were about thirty months old. At about this age the parent's concern and interruptions began to interfere more seriously with securing the child's best response, and, since the children were now usually willing to stay alone with the examiner, the mothers were asked to remain in another room during the mental tests.

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[7] Correlation charts, plotting the raw score on the tests against age in days, indicated a very slight advantage for the older children at one month, but none at two or three months. Since the one-month tests were found to be comparatively unreliable, and since it was impossible accurately to determine conceptual age, no correction for age variations was made.

The observation period usually lasted about 50 minutes with the very young infants, the time gradually increasing with age, until at thirty-six months the entire set of observations usually required 2 hours. With few exceptions, the mental tests were given first. The exceptions occurred more frequently with the young infants, who were often asleep or drowsy when brought in. In such cases other tests were made until the child was awake and active enough to respond readily. After the mental tests a series of reflexes were tested, and physiological and anthropometric measures taken. In the early ages the mental tests took up a very small part of the period, but later their length increased, until, at the 30- and 36-month tests, they required between 30 and 45 minutes. It was found necessary to adapt the time of examination to the mother's and the infant's schedule. In so far as possible each baby was brought at a time when it was usually awake and playing, and at the same time of day each month.

But these precautions do not insure, with young infants, a regular and exact procedure of testing. In the early months, responses to a given stimulus depend to a large extent on the child's mood and degree of wakefulness. A child may blink at an approaching object once, but not every time. He may or may not smile when smiled at, depending in part on his physical comfort or discomfort, as well as on the presence of a conditioned social response. Because of this variability, scores cannot be confined to tests applied in a definite serial order, but the order itself must depend on the child, and he may be expected to manifest a given ability at any time during the observation period, even though he failed to do so when a specific opportunity was afforded him.

Another variable factor in infant tests is the rôle played by the examiner. The importance of the examiner in the testing situation was found to change with the age of the child. During the first two months this factor was relatively slight. Soon, however, the children developed an interest in faces, and a tendency to fixate large moving forms. For these reasons, during the tests given in the crib (except when her presence was a part of the test situation) the examiner stood at the end of the crib back of the child's head. In this position she was not in his range of vision and did not distract his regard from the presented test object. A little later, a friendly social attitude made the child happy and responsive, until he developed a fear or dislike of the unusual and of persons he did not know. During this period (which in some cases began as early as seven months and in others lasted as late as twenty-four months), with children who showed this reaction, the examiner effaced herself from the situation as much as possible, remaining quiet much of the time, keeping the child's attention on the toys instead. Only after the children had again become socially cooperative did the examiner find advantageous the personal "rapport" advised in the usual test procedures.

The infants were tested while lying in the crib in the early months. Then, starting with test item 25, some of the tests were given with the child seated at the table in the mother's lap. After about 6 months of age, all of the tests were given with the child sitting at the table, and when he was able he sat alone in a high chair. A period of adjustment to the strange place was often necessary; but if a shy or distressed child was seated at the testing table with toys in front of him and his mother close beside him, he usually became interested in the toys and started to play. When the child had become accustomed to the situation and had forgotten his inhibitions in play, the test materials were substituted for the preliminary toys.

C. THE TEST ITEMS

The test items used in this study were selected on the basis of their probable validity in indicating "mental" development. Gross bodily coordinations and motor tests have been excluded from the series, and will be treated separately in a study of motor development. The mental series includes tests of adaptability or learning and tests of sensory acuity and fine motor (manual) coordinations. The latter are included in the mental series because they seem related to the manual tests (such as the peg boards and formboards and block-building) which occur in most preschool mental tests. The first-year items have been assembled from a number of sources, among them the tests of Kuhlmann (37), Gesell (20, 18), Jones (36), and Lippman (40). The selection of tests used, and, in many cases, the methods of procedure and scoring, have been adapted to meet the conditions and purposes of the entire developmental study. Of the above-mentioned tests, Gesell's, being the most complete, were drawn on most heavily. Beginning with the second year, the tests used were the California Preschool Schedules I and II, which were arranged by Dr. Adele S. Jaffa.[8]

For the purpose of recording the infants' performances, the test items were grouped by months, according to the age levels which had been assigned to them in the studies from which they were taken. A few of the items have been omitted from the final treatment of results, because they failed to elicit differentiating behavior at successive ages, or because they were not observed in a sufficiently large number of the children. The items which have been retained for the study of mental development are given in Table 4 in the order of difficulty found for the 61 Intensive Study infants. The method of securing this difficulty order will be discussed later.

In addition to the list of test items in their difficulty order, Table 4 includes their scale and age placements, and the various groupings used in an analysis of the results.

The items selected for the first year of the study have been organized as a test group, and described in detail

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[8] This test group is a selection from several standardized tests [Gesell (18), Minnesota (25), Merrill-Palmer (53), CAVD (12), Stanford-Binet (55), and Bayley (5)], with the addition of some original items. The new arrangement is not yet standardized, and certain of the items of the final test will probably vary, in a few places, from the items used here.

TABLE 4
MENTAL DEVELOPMENT TEST ITEMS
Listed in Order of Difficulty

(1) Item No.	(2) Name of test	(3) Absolute scale score	(4) C.A. placement	(5) A-B halves	(6) X-Y halves	(7) C-D groups	(8) C' items
1	Postural adjustment when lifted	.05	.5	A	X	C	C'
2	Lateral head movements, prone	.06	.6	B	Y	C	
3	Momentary regard of ring	.06	.6	A	Y	C	
4	Responds to sound	.06	.6	B	X	C	C'
5	Prolonged regard of ring	.12	1.2	B	X	C	
6	Horizontal eye coordination	.12	1.2	A	X	C	C'
7	Responds to voice	.14	1.3	A	Y	C	C'
8	Arm and leg thrusts in play	.14	1.3	A	Y	C	C'
9	Vertical eye coordination	.16	1.4	B	Y	C	
10	Circular eye coordination	.17	1.45	B	X	C	C'
11	Social smile	.17	1.45	A	X	D	
12	Vocalizations	.18	1.55	B	Y	C	C'
13	Turns eyes to light	.24	1.9	B	X	C	C'
14	Free inspection	.30	2.2	A	Y	C	C'
15	Eyes follow pencil	.32	2.3	A	Y	C	C'
16	Anticipatory excitement	.33	2.4	B	X	D	
17	Manipulates ring	.43	2.9	A	Y	C	C'
18	Reaches for ring	.46	3.0	B	X	D	
19	Blinks at shadow	.47*	3.1	B	X	D	
20	Vocalizes to social stimulus	.47*	3.1	B	Y	C	C'
21	Fingers hand in play	.49*	3.2	B	Y	C	C'
22	Reacts to paper on face	.49	3.2	B	X	C	
23	Carries ring to mouth	.52	3.3	A	Y	C	
24	Aware of strange situation	.52*	3.3	A	Y	D	
25	Follows vanishing object	.53	3.35	A	Y	C	C'
26	Anticipatory adjustment to lifting	.54	3.4	A	X	D	
27	Regards cube	.55	3.45	B	X	C	C'
28	Play with rattle	.57	3.5	A	X	C	C'
29	Manipulates table edge	.61†	3.6	A	Y	C	C'
30	Inspects hand	.62	3.65	B	Y	C	C'
31	Closes on dangling ring	.70*	3.95	A	X	D	
32	Turns to sound	.72	4.0	B	X	D	
33	Beginning thumb opposition	.74	4.1	B	X	C	C'
34	Active table manipulation	.84†	4.4	B	X	C	C'
35	Reaches for cube	.88	4.5	A	X	D	
36	Eye cooperation in reaching	1.00*	4.8	A	X	C	C'
37	Partial thumb opposition	1.10	5.1	A	Y	C	C'
38	Picks up cube	1.12	5.2	A	X	C	C'
39	Retains two cubes	1.16	5.3	B	Y	C	C'
40	Regards pellet	1.18†	5.35	B	Y	C	C'
41	Recovers rattle	1.18*	5.35	B	X	C	
42	Discriminates strangers	1.25†	5.55	B	X	D	
43	Vocalizes eagerness	1.30	5.6	B	Y	C	C'

TABLE 4 (*continued*)

(1) Item No.	(2) Name of test	(3) Absolute scale score	(4) CA placement	(5) A-B halves	(6) X-Y halves	(7) C-D groups	(8) C' items
44	Simultaneous flexion and thumb opposition	1.34	5.75	A	Y	C	C'
45	Lifts cup	1.35†	5.8	A	X	C	
46	Paper play	1.35	5.8	A	X	C	C'
47	Accepts 2nd cube	1.37	5.85	A	Y	C	
48	Vocalizes pleasure	1.38	5.9	B	Y	C	
49	Vocalizes displeasure	1.39*	5.95	A	Y	C	
50	Reaches persistently	1.46	6.05	B	X	D	
51	Turns after spoon	1.47	6.1	A	X	D	
52	Mirror image approach	1.47*	6.1	B	Y	C	
53	Picks cube deftly	1.52†	6.2	A	Y	C	C'
54	Several syllables	1.54	6.3	A	X	C	
55	Bangs in play	1.57	6.35	A	Y	C	
56	Sustained inspection of ring	1.59	6.4	B	X	D	
57	Unilateral reaching	1.61	6.45	A	Y	C	C'
58	Vocalizes satisfaction	1.62	6.5	B	Y	C	C'
59	Lifts cup by handle	1.65	6.6	B	X	C	C'
60	Exploitive string play	1.72	6.7	A	X	D	
61	Rotates wrist	1.75	6.7	B	Y	C	C'
62	Scoops pellet	1.84	6.8	B	Y	C	C'
63	Smiles at image	1.95*	7.2	A	Y	C	C'
64	Interest in bell details	1.95	7.2	B	X	D	
65	Looks for spoon	1.96	7.25	A	X	D	
66	Frolic play	1.97	7.3	B	X	D	
67	Pulls string: secures ring	1.98†	7.35	A	X	D	
68	Vocal recognition	2.00*	7.4	A	X	D	
69	Sound production, interest	2.09*	7.6	A	X	D	C'
70	Complete thumb opposition	2.10†	7.65	B	Y	C	C'
71	Partial finger prehension	2.22	7.8	A	Y	C	C'
72	Retains 2 of 3 cubes	2.30†	8.0	B	Y	D	C'
73	Vocalizes interjections	2.35	8.1	B	Y	C	C'
74	Attends scribbling	2.35†	8.1	B	X	D	
75	Cooperates in games	2.49	8.45	A	X	D	
76	Exploits formboard and block	2.51	8.5	A	X	D	
77	Listens to familiar words	2.51	8.5	A	Y	D	
78	Says *da-da* or equivalent	2.55	8.55	B	X	C	C'
79	Explores formboard holes	2.57	8.6	B	X	C	C'
80	Attempt to secure 3 cubes	2.61	8.7	A	Y	D	C'
81	Interest in throwing	2.69*	8.9	B	Y	D	C'
82	Fine prehension	2.90	9.3	B	Y	C	C'
83	Pulls string adaptively	2.97†	9.5	B	X	D	
84	Uses handle: secures cube	2.99	9.6	A	X	D	
85	Play to mirror	3.07*	9.7	B	Y	D	
86	Differentiates words	3.13	9.8	A	Y	D	
87	Rings bell purposively	3.16	9.9	B	X	D	
88	Puts cube in cup	3.41†	10.4	A	X	D	
89	Scribble imitation attempt	3.42†	10.4	B	X	D	

TABLE 4 (*continued*)

(1) Item No.	(2) Name of test	(3) Absolute scale score	(4) C.A. placement	(5) A-B Series	(6) X-Y Series	(7) C-D grouping	(8) C' Group
90	Unwraps cube	3.59	10.6	A	X	D	
91	Holds crayon adaptively	3.75†	11.2	A	Y	D	
92	Inhibits on command	3.86	11.5	B	Y	D	
93	Repeats: laughed at	3.89†	11.6	A	Y	D	
94	Strikes doll imitatively	3.89	11.6	B	Y	D	
95	Imitates words	3.92*	11.7	B	Y	D	
96	Spoon imitation	4.11	12.1	B	X	D	
97	Holds cup to drink	4.12*	12.2	B	Y	D	
98	Adjusts round block	4.29	12.6	A	X	D	
99	Says two words	4.44*	12.9	A	Y	D	
100	Dangles ring by string	4.49	13.1	A	X	D	
101	Spontaneous scribble	4.51	13.2	B	X	D	
102	Expressive jargon	4.66	13.5	B	Y	D	
103	Tower of 2 cubes	4.66	13.5	B	X	D	
104	Places 1 peg repeatedly	4.73†	13.7	A	Y	D	
105	One block in Bayley board	5.20	15.1	B	X	D	
106	Round block in Gesell board, reversed	5.24	15.2	A	X	D	
107	Looks at pictures	5.34†	15.5	A	Y	D	
108	Throws a ball	5.43†	15.8	B	Y	C	
109	Tower of 3 cubes	5.60	16.3	B	Y	D	
110	Turns pages	5.66	16.6	A	X		
111	Square or triangle in Gesell board	5.72	16.8	B	X		
112	Places pegs in 70″	5.85†	17.2	A	Y		
113	Two round blocks in Bayley board	5.86†	17.2	B	Y		
114	Names 1 object	5.92*	17.4	A	X		
115	Puts cover on box	5.93	17.5	A	X		
116	Places pegs in 42″	5.94	17.5	A	Y		
117	Mends broken doll	6.05	17.7	B	X		
118	Imitates a stroke	6.05*	17.8	A	X		
119	Finds one object	6.16†	18.1	A	X		
120	Places pegs in 38″	6.18	18.2	A	Y		
121	Names 1 picture	6.32	18.7	B	X		
122	Differentiates scribble and stroke	6.36*	18.9	B	Y		
123	Names Gesell watch, 5th picture	6.52	19.4	A	Y		
124	Names 2 objects	6.56	19.6	B	X		
125	Names Gesell watch, 4th picture	6.56	19.6	B	Y		
126	Discriminates cup and plate	6.65	19.8	B	X		
127	Turns door knob	6.72	20.0	B	Y		
128	Square or triangle in Gesell board, reversed	6.75	20.1	B	X		
129	Bayley board, also 2 squares	6.80	20.2	A	X		
130	Finds 2 objects	6.83	20.4	B	X		

TABLE 4 (*continued*)

(1) Item No.	(2) Name of test	(3) Absolute scale score	(4) CA placement	(5) A-B halves	(6) X-Y halves	(7) C-D groups	(8) C' items
131	All 3 blocks in reversed board	6.91	20.6	B	X		
132	Points to 3 pictures	6.93†	20.7	A	X		
133	Places pegs in 30"	7.00	21.0	B	Y		
134	Discriminates cup, plate, box	7.06†	21.1	A	Y		
135	Names 3 pictures	7.08*	21.2	B	Y		
136	Builds tower of 6 cubes	7.10	21.3	B	Y		
137	Names 3 objects	7.18	21.5	A			
138	Differentiates tower and pyramid	7.30*	22.0	A			
139	Completes Bayley board in 150"	7.59	22.8	A			
140	Points to 5 pictures	7.67	23.1	B			
141	Bayley board in 90"	8.03	24.3	A			
142	Names 5 pictures	8.05	24.4	B			
143	Names Gesell watch, second picture	8.07*	24.5	A			
144	Imitates strokes, vertical and horizontal	8.21	24.9	B			
145	Understands 2 prepositions	8.23	25.0	A			
146	Points to 7 pictures	8.28†	25.1	A			
147	Builds tower of 8 cubes	8.36†	25.3	A			
148	Selects "big" object	8.38	25.4	B			
149	Memory: 1 object	8.72	26.5	A			
150	Bayley board in 60"	8.75*	26.6	A			
151	Places pegs in 22"	9.00	27.4	A			
152	Four-form card, 2 correct	9.01	27.5	B			
153	Understands 3 prepositions	9.18	28.0	A			
154	Form card, 1 correct	9.18	28.0	B			
155	Builds 3-cube pyramid	9.20	28.1	B			
156	Points to "tiny" square	9.29	28.3	A			
157	Picture completions, 1 correct	9.32†	28.4	B			
158	Form completions, 1 correct	9.77	29.8	A			
159	Imitates + second trial	9.82†	29.9	B			
160	Memory: 2 objects	9.82	29.9	A			
161	Bayley board in 45"	9.87	30.1	B			
162	Picture completions, 2	9.96	30.4	B			
163	Four-form card, 4	9.99	30.6	B			
164	Buttons 1 button	10.18	31.1	B			
165	Form card, 2	10.29	31.5	B			
166	Action agent, 2	10.42	31.9	A			
167	Picture description: adjective or verb	10.46	32.0	A			
168	Imitates + first trial	10.61	32.4	B			
169	Names 7 pictures (composite)	10.76†	32.9	A			
170	Form completions, 2	10.83	33.1	A			
171	Action agent, 5	10.85	33.3	B			
172	Form card, 4	10.97	33.6	A			
173	Builds pink tower in 75"	11.00	33.8	B			

TABLE 4 (*continued*)

(1) Item No.	(2) Name of test	(3) Mont. [illegible] scale score	(4) C.A. placement	(5) A-B halves	(6) X-Y halves	(7) C-D groups	(8) C' items
174	Knows 5 prepositions	11.08	33.9	B			
175	Pink tower in 40"	11.13	34.1	A			
176	Pink tower in 28"	11.25	34.5	B			
177	Copies 1 circle, 3 trials	11.28	34.6	A			
178	Discriminates long line	11.29	34.7	B			
179	Action agent, 9	11.41	34.9	A			
180	Form card, 7	11.43	35.1	A			
181	Remembers 1 of 4 pictures	11.61	35.6	A			
182	2 buttons in 75"	11.92	36.6	A			
183	Action agent, 12	12.05	37.0	B			
184	Form completions, 4	12.15	37.3	B			
185	Picture discrimination, uses preposition or pronoun	12.33	37.8	B			

*Items marked * by absolute scale score show increasing difficulty with age.

†Items marked † show decreasing difficulty with age.

Columns (3) to (8) will be explained later in the text: (3) on pages 50 and 51, (4) page 52, (5) page 54, (6) page 57, (7) page 58, and (8) on page 60.

ADDITIONAL TESTS, PASSED BY ONE OR MORE CHILDREN, FOR WHICH NO DIFFICULTY PLACEMENTS WERE MADE

Name of test	A-B half	Name of test	A-B half
Six-cube pyramid	A	Copies gate	B
Copies 3 of 3 circles	B	Copies 1 of 3 triangles	A
Form card, 9	A	Form recognition, 1	B
Form recognition, 2,	B	" " 3	A
" " 5	B	Prepositions on picture, 4	B
Prepositions on picture, 6	B	Right and left	A
Pink tower 19"	A	Pink tower 14"	B
Differentiates 2 and 3	A	Differentiates 3 and 4	B
" 4 and 5	A	Action agent, 14	B
Action agent, 16	B	Opposites, 1	A
Opposites, 2	B	Pictures, past or plural	A
Pictures, interpretation	A	Definitions, 1	A
Definitions, 2	B	" 3	B
" 4	A	Memory, 6	B
Form completions, 7	A	Picture completions, 3	B

in another paper (6). The California Preschool Tests are now being prepared for publication.

D. LIMITS OF TESTING

Each test was repeated at successive visits until the child passed it two months in succession, and the advanced tests were always given until a difficulty level was reached where no tests were passed. As a rule this did not unduly prolong the time of the tests with the infants under one year, because many of the test procedures are scored simultaneously at several difficulty levels.

E. METHOD OF SCORING

For the purposes of the present study, a point score was used throughout the three-year period. A child's score at any given age was cumulative and unweighted, obtained each month by adding the sum of his new successes to the previous score. If he failed an item which he had passed at the previous visit this item was subtracted from the score at the month in which he failed it, and added later when it was again passed. Some of the earlier successes, by their very nature, dropped out with maturation, so that even though they did not specifically occur in the later months, credit was not deducted. Examples of these are: arm thrusts in play at one or two months; carries ring to mouth at three months; manipulation of the table edge at four and five months; prolonged inspection of the ring, and bangs in play at six months. Since the child did things which were on a more mature level, he was automatically given credit for such tests as these, which he had passed when younger. In a few instances a test was not passed by a child at any visit. After the child had definitely established a "basal" at an age above this unpassed test, the scoring procedure was to adjust his point score to the higher basal, rather than to penalize him longer for failure to perform at an outgrown level of behavior.

In working out norms for placements of the individual items a somewhat different procedure was followed. Here a success was not counted until it had been achieved two months in succession, although the first of the two consecutive successes was used as the age of passing. This was done in order to eliminate to some extent chance successes which might have resulted from random activity or an insufficiently discriminating subjective judgment on the part of the examiner. If, during the first year (the period of most rapid growth), a child failed a test a *month* after the first success was recorded, it is very likely that the early success was not a real indication of ability. As another precaution against erroneous difficulty placements, first successes following an absence or an omission at the regular preceding test age were not included in the norming of any item. Thus, if a child passed a test for the first time at nine months but had not been tested at eight months, this case was not used in the placing of that item, as there is no sure way of knowing whether the child might have passed the test at eight months. In this way the norms were based on the most accurate possible measure of first appearance of an ability (within the standard one- or three-month intervals of testing), while the individual child's point score was that which he would have obtained on the basis of a single test, scored independently of earlier or later achievements.

To recapitulate, then, the total test score assigned to each child for each test is a cumulative point score based on his actual successes at that test period. The difficulty placements of the individual test items, on the other hand, are obtained from the first of two successive passes of those cases in which the child had been given, and failed, the item at the previous age level.

III

RESULTS

A. RELIABILITY OF THE TESTS

Since it was not feasible, under the conditions of the testing program, to repeat an entire test within a short interval, the reliability of the tests was computed by the split-half method. For this purpose, items were paired on the basis of similarity in difficulty, in nature of the function tested, and in range of successes. Similarity of function, while of necessity judged subjectively, still seemed important to consider when dividing the tests into as nearly as possible "identical" halves. Unfortunately, it was not always possible to find for any given item a mate which was similar both in function and in difficulty. In such cases, unlike items of approximately equal difficulty were paired. In addition to the difficulty placement, the age range and dispersion of the distributions of first passes were taken into account. After the items were paired they were arranged into Groups A and B, with the groups, as nearly as possible, equal in the variety of performances tested and in difficulty at each month. This division into A- and B-halves was done with great care for the first-year items, but in a more cursory way for the second- and third-year tests, as these latter were grouped before complete information on the difficulty placements could be obtained.

From Table 5 it will be observed that the reliability of the total test (using the Spearman-Brown correc-

TABLE 5

SPLIT-HALF (A x B) RELIABILITY CORRELATIONS FOR EACH AGE TESTED

Month	No. of cases	σA	σB	r	r for total test
1	52	.73	1.02	.462	.632
2	58	1.16	1.44	.341	.509
3	61	1.86	2.04	.590	.742
4	58	2.55	2.54	.769	.869
5	58	3.34	2.88	.827	.905
6	57	5.04	4.09	.905	.950
7	52	3.92	3.97	.867	.929
8	53	3.47	3.52	.866	.928
9	56	2.78	3.36	.706	.828
10	56	2.51	2.65	.716	.834
11	52	2.43	1.94	.751	.858
12	53	2.05	2.04	.609	.757
13	53	2.47	2.50	.645	.784
14	46	2.30	2.37	.602	.751
15	53	2.75	2.56	.754	.860
18	51	3.66	2.92	.860	.925
21	53	4.08	3.38	.702	.825
24	48	4.52	3.30	.665	.798
27	51	4.67	3.62	.782	.878
30	47	5.00	3.72	.805	.892
36	49	5.19	4.74	.725	.841

tion) is for most months above .80.[9] The average is .82. In the first three months, however, it is low (.51 to .74); it is also low from twelve to fifteen months (.75 to .78). The highest values are reached between five and eight months (.91 to .95). Since the fluctuations in reliability seem to be influenced by factors other than chance, they call for a word of interpretation.

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[9] These correlations could be corrected for variability differences, making all standard deviations approximately equal to the six-month standard deviations, or 5.0. But if this were done, the increase in the size of the standard deviations for the early months would be relatively so great that the correction does not seem justifiable.

Although the items were selected with the hope that there would be an approximately equal number for each age level, their actual distribution in difficulty turned out to be uneven, with many more items near six months in difficulty than near twelve months. Such a distribution increases the reliability of the tests for the ages at which there are many items entering into the total score, and decreases it where the items are few.

Since the A- and B-halves were selected with great care during the first twelve months, it seems unlikely that the sudden decrease in the split-half reliability correlations after eight months is due to a less adequate pairing of the items at these ages.

It is possible, also, that at some ages the test items used in this study depend more largely on maturation than on environment and training, and hence are more reliable than at other ages where the reverse conditions hold.

Further differences in reliability may be inherent in the different maturity levels tested. In the neonate, behavior patterns are not yet firmly established and the responses to a stimulus are diffuse and varied, making it impossible to obtain reliable measures of mental maturity through short-time observations. When these patterns become stabilized the reliability of the tests increases and stays high, up to a point where a greater diversity of response is possible and where another variable factor enters with the development of social attitudes. At the ages when the children are most likely to be disturbed by the unusualness of the place and testing situations, the test reliabilities fall. They gradually increase again as the children develop in social adaptability and become positively responsive to adult requests.

The correlations between total scores in tests given at adjacent months may also be considered indicative of reliability, especially between months 7 and 15, where the monthly increment is small enough so that the two tests involve, for the most part, the same items, and a similar level of ability. These correlations (Table 8) follow the same trends as the split-half correlations; they indicate low reliabilities during the first four months and fairly high ones thereafter, especially at six and seven months. If we select those successive tests which are sufficiently similar to be considered retests, that is, the eight combinations from months 7 to 15, inclusive, we find that the correlations range from .73 to .87, with an average of .80. The correlations of consecutive tests for the whole series, from month 5 through month 36, range from .71 to .89, and average .82.

Both of the foregoing sets of correlations show that the tests, after month 3, with the possible exception of months 12, 13, and 14, are as reliable as most preschool and infant tests of intelligence.[10] Goodenough (23) obtained, for two-, three-, and four-year old children on the Kuhlmann-Binet, a correlation of .81 between tests given four weeks apart. On the recent Minnesota Preschool Scale (25) the reported reliabilities are higher, the average for a single form of the scale being .89. Linfert and Hierholzer (39), in their first-year mental tests, using the split-half method, with the Spearman-Brown correction, obtained an average correlation of .81.

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[10] A further revision of this scale should be concerned, primarily, with the addition of tests at and near the one-year level of ability; and the substitution, if possible, of more reliable measures of abilities in the first four months.

It seems possible, then, after month 3, to draw conclusions in regard to growth trends with a fair amount of confidence in the reliability of the testing instrument. This is especially true if the average score on two or three tests is taken as a measure of the child's performance.

TABLE 6

CUMULATIVE POINT SCORES: MEANS, MEDIANS, AND S.D.'s

Month	No. of cases	Mean of total	Median of total	S.D.*	Mean of boys	Mean of girls
1	52	4.58	4.54	1.50	4.65	4.50
2	58	11.60	11.65	2.13	11.71	11.48
3	61	18.48	18.14	3.47	19.19	20.27
4	58	28.76	29.07	4.79	30.13	27.29
5	58	38.31	39.00	5.94	39.97	36.41
6	57	48.93	51.00	8.92	51.50	46.07
7	52	60.90	61.50	7.62	62.63	59.04
8	53	70.98	72.25	6.75	72.40	69.71
9	56	78.27	78.50	5.52	78.11	78.41
10	56	85.77	86.50	4.78	85.04	85.79
11	52	91.04	91.75	4.10	90.71	91.42
12	53	96.06	96.38	3.67	95.85	96.27
13	53	100.28	100.67	4.50	101.08	99.52
14	46	104.41	104.90	4.30	104.55	104.29
15	52	107.92	107.64	5.01	108.54	107.31
18	51	118.59	118.00	6.36	117.88	119.32
21	53	130.87	130.75	6.94	129.96	131.74
24	48	141.48	141.50	7.43	141.15	141.86
27	51	150.51	152.00	7.84	149.15	151.92
30	47	158.04	157.17	8.29	157.32	158.86
36	49	172.41	173.00	9.22	170.52	174.37

*For months 13-36 smoothed standard deviation values (obtained from a curve fitted by eye) were used in calculating sigma scores. The smoothed S.D.'s are, respectively, 4.17, 4.63, 5.13, 6.20, 6.94, 7.43, 7.84, 8.29, and 9.22.

B. GROWTH TRENDS

The means and standard deviations of the raw cumulative point scores are shown in Table 6. The means for the sexes have been computed separately, but these are so very similar that all further computations have been made for the total group only. The number of cases in the sex groups would have been too small to yield reliable differentiations.

Since there is an unequal distribution of the test items in difficulty, a growth curve plotted from these is of significance mainly in showing, especially in the first year, the rapid change in scores and the importance of chronological age in determining a child's score. When

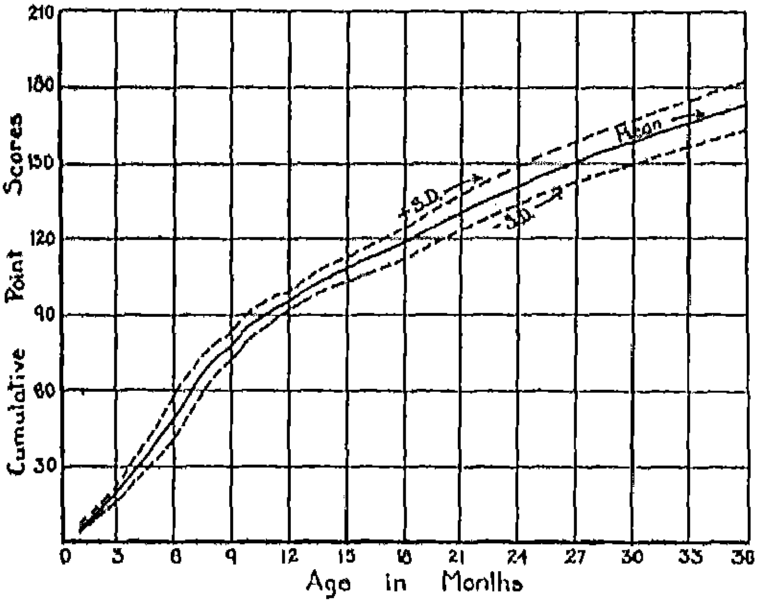

FIGURE 1

MENTAL GROWTH CURVE: CUMULATIVE POINT SCORES the standard deviation is taken into consideration it is found that the overlapping of scores at consecutive months is very slight (Figure I). Throughout the first year, where the correlation between CA and score is .981, the mean plus one standard deviation for any month is lower than the mean for the next test above. From fifteen months on, when the testing intervals have

TABLE 7

PERCENTAGE OF OVERLAPPING BETWEEN SCORES IN SUCCESSIVE TESTS

Tests one month apart		Tests two months apart		Tests three months apart	
Months	%	Months	%	Months	%
Percentage of one age exceeding the median of a higher age					
1- 2	0.0	1- 3	0.0	9-12	0.0
2- 3	0.0	2- 4	0.0	12-15	0.0
3- 4	0.0	3- 5	0.0	15-18	1.92
4- 5	0.0	4- 6	0.0	18-21	5.88
5- 6	1.72	5- 7	0.0	21-24	7.55
6- 7	3.45	6- 8	0.0	24-27	4.17
7- 8	1.92	7- 9	0.0	27-30	11.76
8- 9	5.66	8-10	0.0		
9-10	7.14	9-11	0.0	Tests six months apart	
10-11	8.93	10-12	0.0		
11-12	5.77	11-13	0.0	18-24	0.0
12-13	11.32	12-14	1.89	24-30	4.17
13-14	18.87	13-15	3.77	30-36	4.26
14-15	15.22				
Percentage of one age below the median of a previous age					
1- 2	0.0	1- 3	0.0	9-12	0.0
2- 3	3.29	2- 4	0.0	12-15	1.92
3- 4	1.72	3- 5	0.0	15-18	0.0
4- 5	8.62	4- 6	0.0	18-21	3.77
5- 6	15.52	5- 7	0.0	21-24	4.17
6- 7	9.62	6- 8	0.0	24-27	17.65
7- 8	13.21	7- 9	0.0	27-30	23.40
8- 9	17.86	8-10	0.0		
9-10	8.93	9-11	0.0	Tests six months apart	
10-11	11.54	10-12	0.0		
11-12	11.32	11-13	3.77	18-24	0.0
12-13	16.98	12-14	2.17	24-30	2.13
13-14	21.74	13-15	1.92	30-36	2.04
14-15	25.00				

increased to three months, this same condition holds, through twenty-seven months. After this, the standard deviation increases in proportion more rapidly than the mean score, and with the increasing overlap in scores of consecutive tests the chronological age differences in test ability diminish, though they are still obvious.

Another way of showing this rapid growth in the group is by Table 7, which shows the percentage of overlapping in scores at different ages. The first column gives the percentage of scores of a given month which exceed the median score of the month succeeding. For the first five months there is no case in which a score overlaps the median of the month above. After this, there is a slight overlapping, which tends to increase with increasing age. But if tests separated by two months are compared, no score overlaps the median of the scores two months above, during the first thirteen months. If the comparison is made in the other direction, i.e., the percentage of scores in any given monthly test which are lower than the median of the previous test, there is slightly more overlapping. But still, when two-month intervals are compared, there is no overlapping of the lower median until after twelve months. Making the same comparisons for three-month intervals, no score exceeds the median of the higher test until fifteen months, and no score falls below the median of the next lower test until twenty-one months. The trend is toward an increasing amount of overlapping of scores with increasing age. During the first six months the overlapping between scores only one month apart is less than between the entire six-month intervals from twenty-four to thirty and from thirty to thirty-six months. On the other hand, in comparison with school-age tests, where scores of ten-year-olds, for example, may range from 7.5 to 13 years in mental age (62, p. 31), the marked importance of CA is still evident through thirty-six months.

As for the actual form of the curve of mental growth, Thurstone[11] has plotted an absolute scale curve based on our data for the first twenty-four months. The curve shows positive acceleration during the first seven or eight months; then a very slight negative acceleration during the rest of the first year is followed by a comparatively constant rate from fifteen through thirty-six months.[12] An extension of this curve by the same method, for data through thirty-six months, indicates that this constant growth rate continues up to this age (Figure 2).[13] Whatever growth changes are being measured here, it is obvious that during the first year they are very rapid—more so than mental growth at any later period of life which has been measured.

An inspection of the standard deviation curve

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[11] This article by L. L. Thurstone is not yet published.

[12] Steckel's (52) curve, using the Thurstone absolute scaling method, and based on the Gesell data, is negatively accelerated from its start at four months. However, her data differ from those of the present study in two important respects. Her percentages are based on the letter ratings given by Gesell (18) rather than on the original figures, and the Gesell items include gross motor coordinations, which have been excluded from the present mental development scale.

[13] When the curve was drawn on a larger, less selected sample, extending from 21 through 96 months, by Miss G. Cox, it was found to exhibit a fairly steady deceleration throughout that period.

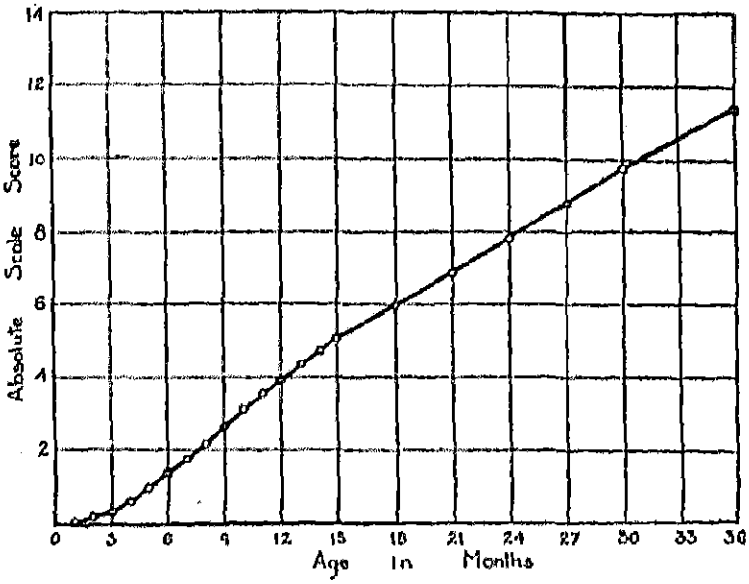

FIGURE 2
MENTAL GROWTH CURVE: THURSTONE ABSOLUTE SCALE

(Table 6 and Figure 3) does not give such clear-cut results. If one were measuring some single mental character, one would expect to find (since the sample of children tested remains constant) either a fairly constant standard deviation or one showing a consistent directional change. But, in the present test series, the standard deviations of the cumulative point scores increase steeply from one to six months, then with a sharp break make an equally steep decrease to twelve months. After this a gradual increase continues throughout the second and third years.[14]

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[14] The curve of standard deviations derived by Thurstone's absolute scaling does not show this break so clearly, though there is evidence of a stationary S.D. between 9 and 12 months, instead of the continuous increase found earlier.

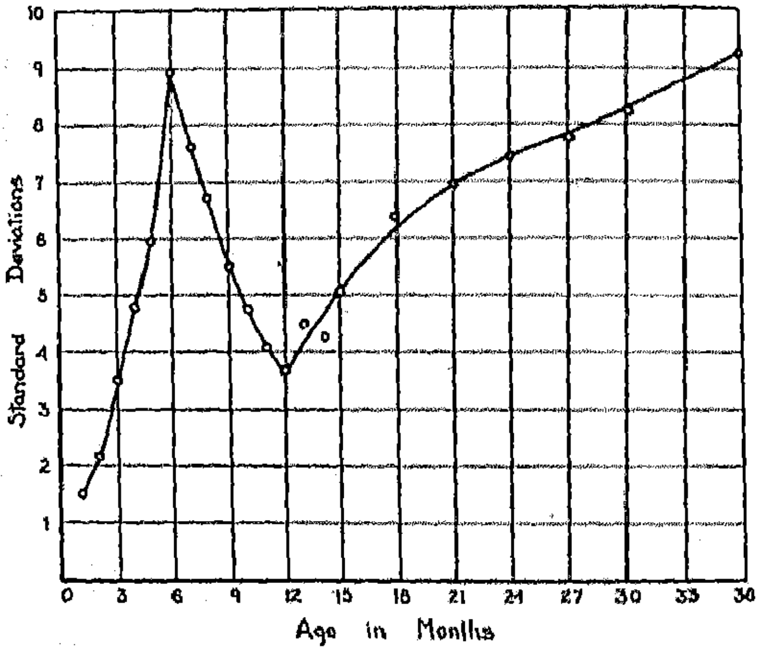

FIGURE 3
STANDARD DEVIATION CURVE: CUMULATIVE POINT SCORES

What is the reason for the sudden check and decline in the increasing standard deviations during the second half of the first year? There seem to be two possible explanations. If the items were so unevenly distributed that a very large number of them clustered together at one age position while at another age they were very scarce, then there would be greater chance for wide variation in the raw point scores at the ages where there were many items. Another possible cause of the sudden change in variability of scores could be in the arbitrary joining together in the growth curve of different kinds of function, developing at rates independent of one another, but at adjoining CA periods. That is, if, for the first eight or ten months, the test items measure predominantly one kind of developing ability which reaches, toward the end of this time, approximate maturity, while the tests from eight or ten months on become, rather abruptly, measures of another kind of developing ability which matures later, and probably started later—if this were so, then it would follow that as the early set of abilities reached the approximate limit of development (where the tests did not discriminate individual differences), the standard deviation must *decrease;* while a subsequent shift to measures of another type of ability would again change the trend of the standard deviations so that they would increase with increasing development in this new function.

A study of the nature and distribution of the test items, which will be considered in Section D, should indicate the extent to which these two factors have been operative in the present series of tests.

C. CONSISTENCY OF MENTAL RATINGS

As we have seen in discussing the reliability of the tests, correlations between consecutive tests, even though there is a lapse of a month or more between tests, are for the most part high (Table 8). They average .82.[15] But when alternate tests are compared (Table 8), and

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[15] If these coefficients are corrected for attenuation on the basis of the split-half reliabilities, they average .95. However, the correlations between some of these adjacent tests may, in themselves, be considered as reliability coefficients.

TABLE 8

CORRELATIONS BETWEEN MENTAL SCORES MADE ON CONSECUTIVE TESTS AND ON ALTERNATE TESTS

Consecutive tests			Alternate tests		
Correlation between scores in months	No. of cases	r	Correlation between scores in months	No. of cases	r
1 and 2	51	.35	1 and 3	52	.62
2 and 3	58	.59	2 and 4	55	.51
3 and 4	58	.68	3 and 5	58	.48
4 and 5	56	.69	4 and 6	56	.60
5 and 6	55	.83	5 and 7	52	.71
6 and 7	49	.89	6 and 8	51	.72
7 and 8	47	.85	7 and 9	50	.75
8 and 9	50	.79	8 and 10	49	.72
9 and 10	55	.81	9 and 11	51	.83
10 and 11	52	.84	10 and 12	51	.72
11 and 12	49	.87	11 and 13	48	.68
12 and 13	50	.73	12 and 14	44	.79
13 and 14	45	.84	13 and 15	49	.77
14 and 15	43	.82	14 and 18	44	.68
15 and 18	50	.75	15 and 21	50	.64
18 and 21	51	.71	18 and 24	45	.64
21 and 24	47	.83	21 and 27	51	.77
24 and 27	47	.86	24 and 30	42	.87
27 and 30	45	.84	27 and 36	47	.86
30 and 36	46	.85			

the intervals between tests become, for the first year, two months instead of one, and for the later tests, six months instead of three, the correlations drop. They average only .70. This definite decrease in relationship for such short time intervals raises the question of the consistency in the scores obtained in more widely separated tests.

For comparisons over wider age intervals, in order to rule out chance variations in a single test, the average of three consecutive tests was used as the score for a given age level. In order that each test should have equal weight in these comparisons, sigma (standard

TABLE 9

CORRELATIONS BETWEEN AVERAGE SIGMA SCORES

	Average Sigma Score in Months					
Average Sigma Score in Months	4, 5, and 6	7, 8, and 9	10, 11, and 12	13, 14, and 15	18, 21, and 24	27, 30, and 36
1, 2, and 3	.57	.42	.28	.10	—.04	—.09
4, 5, and 6		.72	.52	.50	.23	.10
7, 8, and 9			.81	.67	.39	.22
10, 11, and 12				.81	.60	.45
13, 14, and 15					.70	.54
18, 21, and 24						.80

deviation) scores were computed for every test (each child at each age), and the average of three consecutive sigma scores was used; that is, the average of the sigma scores for months 1, 2, and 3 was correlated with the average for months 4, 5, and 6. Test scores were in this way grouped in threes through thirty-six months. The results are shown in Table 9. This series of correlations, with remarkably consistent trend, shows that, though the children remain relatively stable in their scores over short periods, their position in the group is liable to great variation over longer age intervals. There is no significant relationship between a child's scores in the first three months and those he makes after nine months (the correlation with months 10, 11, and 12 is .28); or between his average score in months 7, 8, and 9 and his performance in the third year (the correlation is .22).

There is, however, a tendency for the sigma scores to become more stable as the children grow older. Although this is not evident from Table 9, if we compare tests equally distant from each other in absolute scale units of ability, we find that the older the children the higher the correlation coefficients between sigma scores. This is shown in Table 10. The absolute units are based on the Thurstone growth curve and the increment in these units was roughly computed, from the average of the first three months to the average of the second three months, and so on. Selecting from Table 9 pairs between which the absolute scale increments are approximately equal, and arranging them in age order, we find a tendency to greater stability with growth, even though over wide intervals the correlations become very low, and there seems to be no basis for predicting later achievements from these early test scores.

There are several possible explanations of this lack of consistency in the test scores. Each child may have, during this early period of rapid growth, an inde-

TABLE 10

COMPARISON OF CORRELATIONS BETWEEN TESTS SEPARATED BY SIMILAR ABSOLUTE SCALE INTERVALS

Average of scores at months	Absolute scale interval	*r*
4, 5, and 6 x 7, 8, and 9	1.3	.72
7, 8, and 9 x 10, 11, and 12	1.3	.81
10, 11, and 12 x 13, 14, and 15	1.2	.81
1, 2, and 3 x 7, 8, and 9	2.07	.42
4, 5, and 6 x 10, 11, and 12	2.6	.52
7, 8, and 9 x 13, 14, and 15	2.5	.67
13, 14, and 15 x 18, 21, and 24	2.3	.70
18, 21, and 24 x 27, 30, and 36	2.17	.80
1, 2, and 3 x 10, 11, and 12	3.37	.28
4, 5, and 6 x 13, 14, and 15	3.8	.50
10, 11, and 12 x 18, 21, and 24	3.5	.60
1, 2, and 3 x 13, 14, and 15	4.57	.10
7, 8, and 9 x 18, 21, and 24	4.8	.39
1, 2, and 3 x 18, 21, and 24	6.87	—.04
10, 11, and 12 x 27, 30, and 36	6.67	.45

pendent rate of mental development. These individual growth curves might differ in various ways: by one or more independent cycles of slow and rapid maturation; by consistently differing but steady trends of growth; or by complete irregularity in growth rates.

Intelligence may not be measured in the early months. If so, one could argue that only as this general factor of intelligence becomes increasingly manifested in the test scores can the scores be considered to measure that factor, and only when it becomes predominant will the scores be consistent. Systematic changes in attitude toward the test situation may tend to lower the correlations between scores obtained at ages when the child's social responsiveness, interest in success, and so on, are very different. It does not seem possible, however, that such attitude changes can have a pronounced effect on the scores. It may be that the tests used in this study measure various things, and not a single "intelligence" which can be tapped and evaluated at any convenient stage in a child's development. Rather than a single factor, there may be multiple factors, different ones entering into the score at different age levels. This seems very probable, especially as it is in accord with one explanation offered for the sudden break in directional trend of the standard deviation curve. Since we do not know exactly what intelligence is, we cannot, in the face of this evidence, very well make assumptions about the gradual appearance of "*g*" or its independent growth cycles without first examining the nature of the tests on which these scores are based.

D. ANALYSIS OF THE TEST ITEMS

1. *Order of Difficulty.* The first step in the study of the individual test items was to arrange them in order of difficulty. This was done on the basis of the percentage passing each item at each age. Under the direction of L. L. Thurstone, placements on an absolute scale of difficulty were obtained for each item.

Since, by the method of absolute scaling (56), item placements are based on overlapping performance of age groups, and since there are usually four or more age groups whose performance overlaps, several placements are obtained for each item. Due in part, perhaps, to unavoidable errors in measurement, these placements did not, as a rule, exactly coincide, although they were grouped fairly closely together. To obtain a single score which would probably be more accurate than any one placement taken alone, the mean of all of the placements of an item was computed and used as the scale value. The scale value for each item is given in Table 4. On the basis of these scale placements, the items have been arranged in order of difficulty.

The test items are unevenly distributed in difficulty, a close clustering being found at the lower end of the scale, while at other places there are comparatively wide gaps. This is shown both by the absolute scale placements (Figure 4) and the chronological age placements. Theoretically, however, the former give a better indication of the difficulty grouping because these placements are based on the curve of growth (Figure 2), rather than on chronological age. One

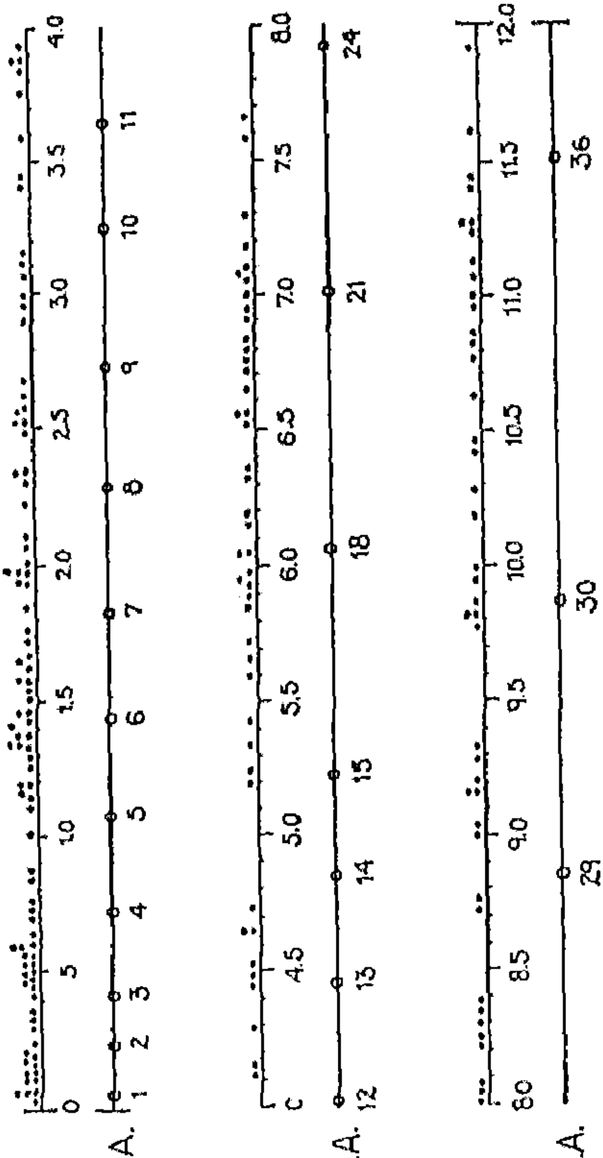

FIGURE 4

Difficulty of Each Item According to Its Absolute Scale Placement (Upper Line of Pair), Together with CA Equivalents (Lower Line of Pair) could have the same number of items placed in each month interval and still have a greater cluster of items at the lower end of the absolute scale (corresponding to the first three or four months), where the increment of growth for a given time interval is smaller; while the reverse would be true a little later, when growth is most rapid.

For convenience in testing and comparison with chronological age the absolute scale placements have been converted into CA placements. This was done from a graph of the absolute growth curve, by finding the point on the CA abscissa which was equivalent to the item placement on the absolute scale ordinate. These placements are given in column 4 of Table 4 and are the ones used in the First Year Mental Scale blanks (6).

As has been mentioned, several placements were obtained for each item, and their average is the value which was finally used. A normal distribution of the ages of first passing an item, such as looking for a fallen toy, should, theoretically, result in the same placement on the absolute scale when the six- and seven-month passes are compared, as when the seven- and eight-month passes are compared (57). If these placements vary greatly at the different overlapping ages, the item would not seem to be a good one to indicate mental growth. As a measure of the consistency of the difficulty placement of an item, the average deviation from the mean placement was computed. Items with a comparatively large average deviation, then, were considered as of doubtful value in a developmental scale. The scatter of individual placements, relative to the standard deviation for the age level, would indicate the consistency of difficulty for that item at successive ages.

In order to determine if the placements are more consistent at some ages than at others, the items for each month were grouped. The mean of the average deviations of the item placements in each age group was then divided by the standard deviation of the absolute scale scores at that age. The items for the first three months show a mean variation of 35.3%, which is much higher than that which occurs at later months (Table 11). After three months, the variation shows no consistent changes except, perhaps, a slight tendency to decrease: from four to twenty-four months,[10] inclusive, the mean variation is 18.4% of the standard deviations. This early variability in the difficulty placements of the tests may be another manifestation of their unreliability during the first three months, but is probably due also in part to the nature of the scaling method, which is less accurate where—as in the early ages—there is little overlapping from one month to the next.

2. *Classifications of the Test Items.* The growth trends of the entire series of tests appear, *a priori,* to be the resultant of a number of underlying factors. It seemed possible to discover, or at least throw some light on, what these various factors are and what independent

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[10] These variations were not computed after 24 months, as the more difficult tests had not yet been passed by all of the 36-month children and their placements were based on an incomplete set of overlapping ages.

TABLE 11

INTERNAL CONSISTENCY OF ABSOLUTE SCALE PLACEMENTS*

Month	Relative variation*	Mean
1	46.5	35.0
2	25.2	
3	34.2	
4	16.1	18.4
5	15.2	
6	20.7	
7	23.0	
8	14.7	
9	17.5	
10	23.9	
11	18.5	
12	21.7	
13	25.9	
14	13.7	
15	18.4	
18	20.4	
21	12.1	
24	13.7	

*The figures in this table are obtained as follows: The mean of the average deviations of the item placements in each age group is divided by the S.D. of the absolute scores at that age.

tendencies they manifest by dividing the test items into subclasses in different ways.

Several classifications on the basis of the apparent functions tested were tried, but seemed to lead nowhere, and are not here treated in detail. A list of some of these may give an idea of the sort of classification attempted. One such grouping divided the items into (1) motor maturation, (2) eye-hand coordination, (3) adaptive coordination, (4) adaptive behavior, (5) reactions to sound, (6) visual maturation, (7) language comprehension, (8) vocalizations, and (9) social responses. This was the most elaborate classification. One fourfold division into (1) vision, (2) motor coordination, (3) vocalizations, and (4) sound and language comprehension left a number of items unclassified. Another, (1) sensorimotor maturation, (2) adaptive behavior, and (3) language comprehension and development, still left a few items out, but in some ways was more satisfactory than the others—perhaps because less elaborate. One reason that these divisions did not prove satisfactory is that in many cases an adequate response to a test situation requires abilities of more than one kind, so that items may equally well be assigned to two or more of the classes. For example, comprehension of the verbal requests made by the examiner is often as much a part of a test as is ability to act upon these requests. Since each test item does not always measure ability in a single function, but usually involves others as well, the basis for classification is an arbitrary one, depending on the investigator's judgment of the relative importance of the functions included.

Another difficulty in the way of a practical division of the test into subgroups is that no two of them show parallel development. The items in them are very unevenly distributed, with the motor and sensory items predominant in the early ages, while the adaptive ones do not appear until later. Such a distribution precludes the possibility of studying the interrelationships of the different functions as they develop.

An attempt was made to find behavioral sequences in a manner similar to that used by Shirley (49) for motor development. It was considered possible that several series of test items might be found that followed, within the series, an invariable sequence of appearance. Such tests would be the resultant of a common developing function and would afford a sound basis for subclasses of the group of test items. There were only a very few items, however, which showed this invariable sequence, unless the items were more than two standard deviations apart on the difficulty scale. These comparisons were made through the first seven months, and out of more than seven hundred combinations of items which were less than two standard deviations apart on the difficulty scale, only 34 showed an invariable sequence. Of these 34, twelve, in which different degrees of facility in the same behavior were scored, followed the sequence by logical necessity. Such a sequence is: reaches for the cube, picks up the cube, picks up the cube deftly and directly. A few of the remainder were closely related in function, such as eye coordination, horizontal, vertical, and circular; but others seemed only slightly related. Eighteen of the 34 pairs could be classified as predominantly motor and seven as visual, but the numbers are so small that it is impossible to make any division of the entire group of tests on the basis of interrelations which the sequential method could indicate.

It was necessary to conclude that there are not discrete functions measured by different test items, and that, for the most part, the sequential order holds only when the items are sufficiently far apart on the difficulty scale to constitute manifestations of a different level of ability. And when they are this far apart the sequential order has little relation to the nature of the items. The only differentiating factor is that items with a greater range in the age of first passes show more reversals in sequence. Whether this would be true of the tests of gross motor development, this study does not show, although the items which did follow in sequence were most often motor items.

Other ways of grouping the tests were suggested, incidentally, by the results of previous statistical treatment. One statistical basis for differentiation was the consistency in the scale placements obtained from the Thurstone scaling. Some of the items were very consistent in the difficulty placements at different ages, others were inconsistent and might be considered, for this reason, less desirable as measures of developmental level.

Some of the items showed a consistent directional deviation from a mean difficulty placement. This directional deviation is the result of skewed age distribution of first passes, and the items exhibiting such a "drift" could also be looked on as possibly less adequate tests of development than other items. Of about 170 items with three or more overlapping age placements, 54 showed a consistent directional shift which was large enough to have some possible significance. Twenty-eight of these grew easier with advancing age, while 26 grew more difficult. The shifts in the latter items were, for the most part, greater than for the former. It seemed possible that there might be some similarity between the items which showed a given tendency—some common characteristic causing either a rapid maturation of the test, once it reached a stage where the function could be manifested, or, on the other hand, some factor which, perhaps, supervened and prevented the appearance of a given response in some children after the general maturity level made it possible.

Inspection of these two groups of items seems to corroborate this assumption (see Table 4, * items become more difficult, and † items easier with age). The items which become easier as the group grows older involved for the most part relatively simple activities, depending on motor or sensory maturation. However, this does not seem to be true of all of them. It is possible that such a decrease in difficulty with age is the effect of practice of a specific behavior, and that motor activities of infants, being generally practiced more, are likely to develop more rapidly, once a sufficient maturity is reached, than do other kinds of behavior.

Those items which grow more difficult, on the other hand, usually involve social adjustments and adaptation to the unusual testing situation. They involve activities which might in the later ages have been inhibited by other developing attitudes.

Since these items with characteristic "drifts" are comparatively few, and inadequate for separate classifications in a division of the entire scale, we decided to use them rather as guides in a more general division. The tests were again divided into halves, equally distributed in number for all ages. (See Table 4, column 6.) The X-half was made up of what seemed to be the better items for measuring mental growth; these were the ones with consistent scale placements, which seemed by inspection to be the more truly adaptive. Into the Y-half we put items whose placements were inconsistent, or which showed a directional drift, items which were difficult for the examiner to score, and items which seemed to have fewer of the "mental" elements. This division differed from the A- and B-halves in that the latter were made as much as possible alike in all respects, barring identical items. The X- and Y-items were paired for difficulty but otherwise the X-half was given the advantage of including all of the items which were considered, for the reasons mentioned above, to be the better measures of mental development. The cumulative scores of these halves were correlated with each other and with the total scores at one, six, and twelve months, and no advantage was found for either group (Table 12). To find if the scores from the X-group might be more predictive of later achievement, the scores for both groups were correlated, each with itself, at 1 x 6, 6 x 12, 4 x 8, and 11 x 15 months. As shown in Table 13, the Y-tests—the discards—were if anything more consistent, the correlations in every case being higher than for the X-

TABLE 12

CORRELATIONS OF SCORES ON X- AND Y-ITEMS

Month	No. of cases	Correlations X x total	Y x total	X x Y
1	52	.895	.846	.520
6	57	.963	.967	.868
12	53	.869	.894	.551

TABLE 13

CONSISTENCY CORRELATIONS OF SCORES ON X-ITEMS, Y-ITEMS, AND TOTAL ITEMS

Months	No. of cases	Correlations X-items	 Y-items	 Total items
1 x 6	48	.084	.349	.295
6 x 12	49	.425	.635	.642
4 x 8	52	.420	.522	.577
11 x 15	49	.503	.559	.623

group though not significantly so. This selection into X- and Y-halves does not seem profitable, since the total scores are more reliable, and neither half shows any real superiority as a measure of mental growth.

One other division of the items seemed worth trying. In previous classifications, it had been obvious that the early tests were predominantly sensorimotor in nature, while items which could be classed as adaptive, or "mental," were not to be found until later. In view of the break indicated by the standard deviation curve (Figure 3), it seemed possible that a division between these two types of performance might result in two distinct but overlapping curves which would correspond to the break indicated in the curve for the total test items. Returning to the earlier classifications, all items which had been classed as sensorimotor and vocal (non-verbal) behavior were grouped together, while the rest of the items, which seemed to be more truly adaptive, were put in another group. These we will call Groups C and D respectively (Table 4). It was found that the C-items dwindled and practically disappeared at about *nine months*, while the D-items, which enter later than the C-tests, are comparatively

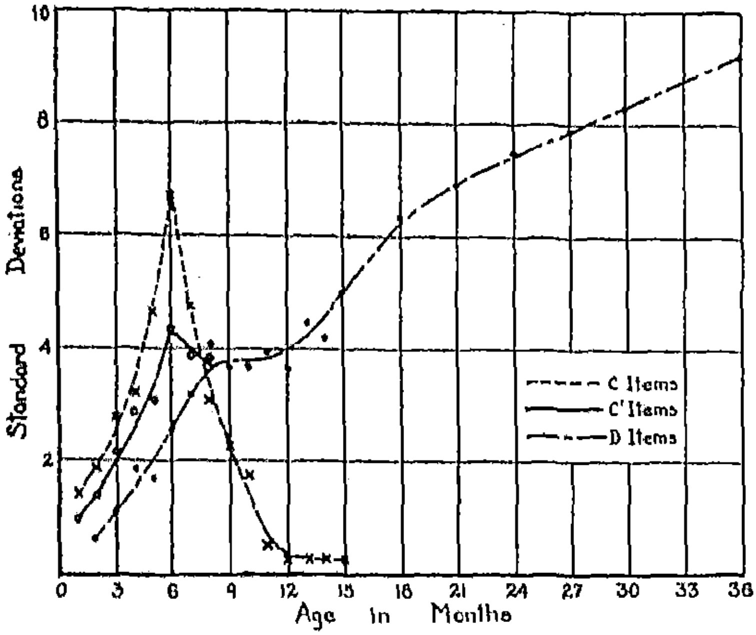

FIGURE 5

Standard Deviation Curves for the Sensorimotor (*C*) and Adaptive Items (*D*) Separately, and for a Selection of Sensorimotor Items Equally Distributed in Difficulty (*C'*)

few and scattered at first, and then become predominant as the C-items drop out.

When the test items are classified in this way, the standard deviation curve of the C-(sensorimotor) group is found to correspond closely to the earlier part of the curve for the total items (Figure 5). But we have seen (Figure 4) that the test items are not evenly distributed over this part of the growth scale; there is a bunching of items at some ages, allowing a wider distribution of scores and so larger standard deviations than at other ages, where items are comparatively scarce. This tendency for relatively very large standard deviations at and adjacent to six months might have been the result of the crowding of items around this point on the difficulty scale, with very few items at any one month after month 9 (Table 4). It is after the age where the great number of six-month items could affect the scores that the standard deviations become very small again.

In order to determine whether this standard deviation trend is due entirely to the unequal distribution of the items, 55 items were selected from the C-group (we may call this new selection C'). These items were selected so that there were five items from each month, and they were placed, within the month, at fairly regular intervals on the difficulty scale. In several levels there were not enough C-items to make the distribution equal; where this happened, D-items involving motor coordinations were used.[17] With an equal number of items at each age, and a normal frequency distribution of scores, there would be no reason to expect a consistent directional change in the standard deviation curve until the age at which the children began to reach the upper limits of difficulty. In this group the standard deviations still show a consistent decrease after six months —exactly the same directional tendency which was found in the total and in the C-group (Figure 5). The standard deviations for the C'-group have not been computed beyond eight months because after this age the difficulty limits of the tests would automatically make them grow smaller.

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[17] The ten items for months 10 and 11 included all tests at these ages and so were necessarily all D-items.

This change in direction of the standard deviation curve cannot, then, be an extraneous effect deriving from the unequal difficulty distribution of the test items, although it is accentuated by the coincidence between the bunching of the test items and the functional trend. And this coincidence may not be due to chance, but in itself may have occurred because of the relative scarcity, at this stage in development, of differentiating tests of the function which has already matured, and of tests of the newly developing function which has not yet become diverse in its manifestations.

Such an explanation is further corroborated by the evidence from the D-items. A distribution of these items in difficulty order by one-month units shows that they are fairly evenly spread, after the first two months, with little bunching. Their distribution on the absolute scale also is very even except for a section (5.6 to 7.1) corresponding to the ages between sixteen and twenty-one months where an unusually large number is found. With such a regular distribution of the items on the difficulty scale, at least during the first fifteen months, the plateau between eight and thirteen months in the standard deviation curve for this group of tests points again to some functional break in the nature of the tests in the second half-year, even when the attempt is made to separate the test items into two functionally different groups.

The standard deviation curve of the cumulative point scores of the adaptive (D) group of items, is, in the later months, identical with the total curve. But the elimination of the sensorimotor (C) items does not, as had been expected, leave it with a smooth, continuous increase. There is a plateau between eight and twelve months, and this has occurred in spite of the fact that the D-group items are quite evenly distributed in difficulty. But it is probably impossible to separate the two types of developmental process in the items in this overlapping period, since many of them include both kinds of function. In the early attempts at item classification, when there seemed any evidence of adaptive behavior a test was put in the D-group, as adaptive items were scarce at the early ages. Such a failure really to exclude sensorimotor elements would account for the plateau of standard deviations in the D-group and also for a more rapid increase in the standard deviations during the first half-year than would be expected from the trend at later ages. If one could segregate these functions into separate responses, the irregularity in the standard deviation curve of the adaptive tests from eight to twelve months might smooth out. However, it may be that maturation in the first half-year is almost exclusively confined to motor and sensory functions which are unrelated to later development,[18] except for their priority in the growth series. If this is true, then the mental growth curve presented here, during the first year at least, is a composite; and it would be more correct to say that the

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[18] Shirley (49, Chap. IX) found very little relationship between the locomotor and intellectual achievements (Minnesota Preschool test at 18 months) of 17 babies studied during the first two years.

TABLE 14

MEANS OF SCORES ON SENSORIMOTOR (C′) ITEMS, ACCORDING TO SEX

Boys				Girls			
Month	No. of cases	Mean	S.D.	Month	No. of cases	Mean	S.D.
1	24	2.46	1.12	1	27	2.15	.80
2	30	6.97	1.49	2	28	6.68	1.19
3	30	11.67	1.86	3	31	10.48	2.68
4	29	18.67	2.57	4	29	16.07	2.79
5	30	23.00	3.02	5	28	21.21	2.97
6	29	28.10	3.99	6	28	25.29	4.31
7	27	33.11	3.78	7	25	31.92	3.94
8	25	38.56	3.15	8	28	36.75	3.69

curve in the first six or eight months is of sensorimotor development rather than of "intelligence."

Since the boys had slightly higher scores throughout the first eight months in the total cumulative point scores, and the early tests were predominantly sensorimotor, some sex difference might be looked for on the basis of this division of the items. The means and standard deviations for the first 45 C′-items were computed for the sexes separately through eight months (Table 14). The boys' scores, again, are consistently *higher for this period, but the difference is still so small* that it may well be due to a chance selection in the cases.

The only item classification, of the various ones tried, which showed any real distinction between the classes was the division into sensorimotor and other (predominantly adaptive) behaviors. These two groups are successive in their appearance, rather than simultaneous, and are coincident with the directional changes in the standard deviation curve obtained for the total scores.

E. VARIABILITY

There are three different ways in which increasing variability in performance is manifested as the children grow older. So long as the functions tested are fairly homogeneous, the total scores of the group become increasingly variable with age. The period between six and twelve months, when this is not true, is a period of transition from a mature group of abilities to a very immature group whose variability is still very small. With the exception of this six-month period, the children tend to become more and more unlike each other in their test abilities as they grow older.[10] This is reflected also in the increasing standard deviations in the ages at which an individual test item is first passed. The items in the early part of the scale have a very small age range of first passes, but as the difficulty increases the variation tends to increase.

In addition to this, we find that the individual children become more variable in the successes they make, as they grow older. This is shown in Figure 6. The range of a child's successes at any month—from the easiest item he passed for the first time to the most difficult he passed—was recorded in absolute scale units of difficulty. These ranges, being extremes, are, for individual children, unreliable measures, but when the averages for the group are considered unreliable

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[10] Although the coefficients of variability, if computed, would decrease with advancing age, they would give no indication of the real variability of the scores, as the range of new successes at any one age covers only a small portion of the total point score. On the other hand, Thurstone's absolute scaling data give added evidence for increasing variability.

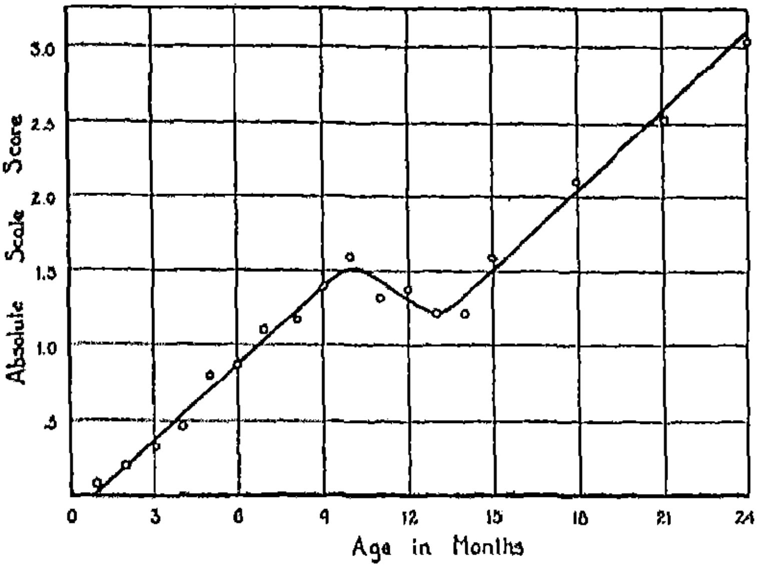

FIGURE 6

CURVE SHOWING THE INCREASING VARIABILITY IN THE RANGE OF SUCCESSES FOR INDIVIDUAL CHILDREN: BASED ON THE AVERAGE OF THE ABSOLUTE SCALE RANGE OF FIRST SUCCESSES FOR EACH CHILD AT EACH AGE TESTED

fluctuations tend to be cancelled out. The mean of the ranges shows a definite increase in the span, or portion, of the difficulty scale covered with increasing age. The one exception, between eleven and fourteen months, coincides with the region of decreased standard deviations of total point scores and the juncture of the two types of test performance.

The general trend toward increasing variability of function within the individual is interesting in view of the contention that a person does not vary much from his "level" of intelligence as measured by tests: that a bright person is generally bright, and a dull person generally dull. Gesell (18) has pointed out the relatively small variability in an infant's performances. A six-months-old child is obviously six months in most of his behavior and distinctly inferior in all respects to the eight-months-old child with whom he is compared. In the first year, especially, age seems to be the all-important factor in a child's development. The correlation of .98 between CA and total point score of the Intensive Growth Study group during the first twelve months indicates far less variable scores than are found later. However, if the tendency for greater variability within the individual, as he grows older, continues at the rate which is indicated by the first two years of these children's performances, then one should expect that adults would show wide differences in their performances if a correspondingly wide sample of behavior were tested. The concept of intelligence is relatively restricted in adults, while, in attempts to measure it in young children, a much more varied range of abilities is necessarily included. It is in these varied abilities that intelligence seems to be manifested, if at all, in young children.

F. CONDITIONS WHICH MAY AFFECT THE SCORES

In the foregoing treatment the test scores have been considered independently of other factors. But there are some environmental conditions which affect or are related to a child's test score, and these should be considered in interpreting the obtained results. Of such conditions we have some data on (*a*) parental ability as measured by education, (*b*) emotional behavior observed under test conditions during the first year, and (*c*) the effect of the play school as a favorable influence.

1. *Education of Parents.* There have been several recent studies of the relationship between the intelligence of parents and young children. For children aged two, three, and four years, using the Kuhlmann-Binet test and a mid-parent education score, Goodenough (23) found positive parent-child correlations, ranging from .26 to .69; there was no consistent change in the coefficients during this period. Van Alstyne (59) obtained for Kuhlmann-Binet MA's of three-year-olds a correlation of .60 with mothers' education, .51 with fathers' education, and .54 with mothers' vocabulary (Thorndike Test of Word Knowledge). Linfert and Hierholzer (39), using a sample aged from one to twelve months, found an average correlation of only .06 between scores on the Linfert-Hierholzer scale and Chapman-Sims scores. They also found no tendency for consistent changes with growth over the period considered. Furfey (14) interprets these last results as evidence for the effects of environment on intelligence, since the correlations during the first year are practically zero, yet other investigators have found positive correlations at later ages, after there had been time for environment to be effective.

In the present study mid-parent education scores of mothers' and fathers' schooling were correlated with the infant's scores for each age separately. These correlations are given in Table 15. When plotted, as in

TABLE 15

CORRELATIONS BETWEEN MID-PARENT EDUCATION SCORE AND CHILD'S POINT SCORE AT EACH AGE

Month	No. of cases	r	Month	No. of cases	r
1	52	—.01±.10	12	53	+.03±.10
2	58	—.02±.10	13	53	—.05±.10
3	61	—.27±.09	14	46	—.02±.10
4	58	—.22±.09	15	52	—.00±.10
5	58	—.29±.08	18	51	+.16±.09
6	57	—.23±.09	21	53	+.29±.08
7	52	—.19±.09	24	48	+.50±.07
8	53	—.05±.10	27	51	+.41±.08
9	56	+.06±.10	30	47	+.44±.08
10	56	+.08±.10	36	49	+.47±.08
11	52	+.00±.10			

Figure 7, a strong directional trend is evident. The correlations at months 1 and 2 are practically zero. They are the least reliable tests and the tests which might have been affected by varying conditions of birth. Starting with month 3 and continuing through month 7, the correlation coefficients are consistently negative, varying around —.22; then from eight to fifteen months, they drop back to zero; after this they become increasingly positive until twenty-four months, and subsequently maintain a level between .41 and .50. These later correlations approach very close to the relationship usually found between parents and school-age children on intelligence tests. For the ages that are the same as in Goodenough's study they show *no* directional changes with age.

The results of Goodenough and of Linfert and Hierholzer are not exactly comparable with those of the present study because the Linfert-Hierholzer study deals with socio-economic status instead of education and neither study uses a constant sample for all ages. It is to be observed that the results of the present study fill in the gap between one and two years, at which age a positive parent-child relationship begins to emerge. Probably because the present sample is constant, the correlations are less variable at adjacent ages than are those of either of the other two studies. Whether the negative correlations obtained between two and seven months are large enough to have any significance is doubtful, since they average only 2.9 times their P.E.'s, but their persistence over a six-month period indicates at least the possibility of a negative relationship between parent intelligence and early infant scores.

The shift in relationship with age may be interpreted as an indication of environmental influence on development. If the correlations are considered to be zero at first, and then increase as the children have time to be influenced by their environment, then this explanation would be a reasonable, though not a conclusive one. It seems more probable, however, when the changing nature of the infant tests is considered, that different abilities are being measured at different ages, and that the later tests are better measures of the abilities which differentiate school achievement. The tendency for the early scores to be negatively correlated with parental education may, if significant, be due to innate differences in developmental rates, with the children who will later achieve higher scores having a slower initial development. Because the nature of infant tests is so radically different from later tests, it is impossible

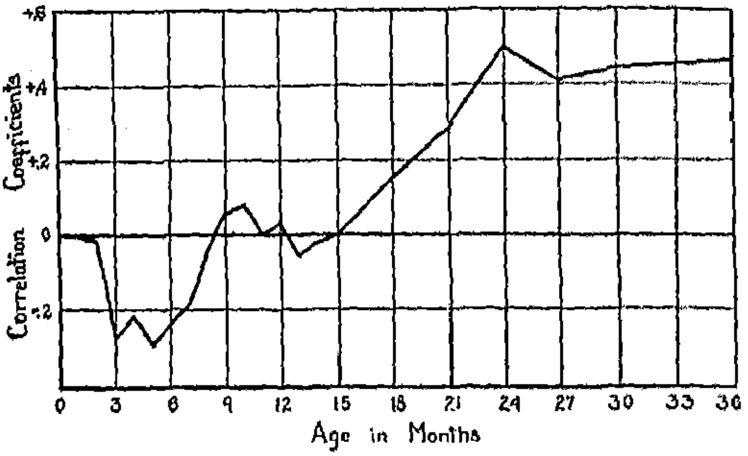

FIGURE 7
AGE CHANGES IN THE CORRELATION COEFFICIENTS BETWEEN MID-PARENT EDUCATION AND CHILD'S MENTAL TEST SCORE

to determine from correlations with parental status whether or not the parent-child relationships are due to environmental influence. But environmental influence is obviously not as great as would appear from a cursory summary of Figure 7.

2. *Emotional Behavior.* The emotionality of the child as evidenced in his tendency to cry is not significantly related to his mental test scores (5). When the amount of crying which occurred during the examination period is stated in terms of the length of time a child cried relative to the time of the total period, the correlation between the percentage of crying and the test scores for the entire first year is —.098 and is similarly low for the separate months during the year. The data on emotional behavior in the second and third years have not yet been summarized, but they are prob-

ably of more importance than the crying during the first year, for the later tests seem to be more affected by a child's social attitude, willingness to follow adult suggestions, and other environmental conditions. The effect of emotional attitude on test scores of preschool children has been pointed out frequently. [See, for example, Bridges (9), Stutsman (53), and Updegraff (58).]

3. *Influence of the Play School.* Sixteen of the Intensive Growth Study children have attended, for varying periods, the Institute play school. The sessions here last for three hours, from 9 A.M. to 12. The mean sigma scores of these children for the average of the two tests before they entered the school is +.08; and for the average of the one, two, or three tests given after the children had been in school for at last four months the mean sigma score is +.40. This is an increase of .32 sigma. The standard error of the difference, taking into consideration the correlation of +.66 between the two sets of scores, has been computed by the formula:[20]

$$S.D._{diff.} = \sqrt{(S.D._{m1})^2 + (S.D._{m2})^2 - 2r_{12}\,S.D._{m1}\,S.D._{m2}}$$

The obtained critical ratio of 2.0 shows that the chances are 98 in 100 that the difference is significantly greater than zero.

To make certain whether this group was selected on the basis of parents' education, the 16 children with school experience were matched for mid-parent education scores with 16 others in the group. The parents of the non-play-school group had a mean education of 14.4 years, as compared with 14.0 years mean for parents of the play-school children. The mean sigma score for the non-play-school group for months 18, 21, and 24 is +.10 and for months 27, 30, and 36 it is +.03. Their scores for the two age levels correlate .88, and the critical ratio of .72 shows that the chances are only 78 in 100 that the difference is significantly greater than zero. Any rise in the test scores of the children after play-school experience cannot, then, be attributed to a selection of the group on the basis of parents' education, although this does not preclude selection on the basis of parents' intelligence.

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[20] Formula 140, page 182 of Kelley's *Statistical Method.*

This increase of the play-school group, which averages .32 sigma, is approximately equivalent to 4 IQ points, and, though slight, its directions is the same as that found by Woolley (63) who compared tests of Merrill-Palmer children with children on the waiting list of the nursery school; and by Barrett and Koch (3) who found large increases in the IQ's (Merrill-Palmer test) of orphanage children after they had attended nursery school over a period of from six to nine months. Wellman (61) has shown recently that children in the Iowa preschool gained more in IQ points from fall to spring when the children were attending the school than from spring to fall when they were not in school. Goodenough (24), on the other hand, found no significant differences between the Kuhlmann-Binet IQ's of 28 children with nursery-school experience and an equal number of paired controls without nursery-school experience.

Of the conditions considered here, the one which shows the greatest apparent effect on the children's scores is the education of the parents. Since there is so little consistency between earlier and later scores on the mental tests, it may be argued that the parent-child relationship cannot be measured until the third year when the behavior tested becomes similar to that measured by the parents' educational level. It is possible, then, to look to change in test-function as one of the causes of the increasing correlations between parents and children. On the other hand, there is some evidence of the environmental influence of the play school on test scores in the third year, and such influence, could we evaluate it adequately, may to some extent be operative throughout all of this early growth period, at home as well as at school.[21]

But regardless of the relative importance of heredity and environment in their effect on test scores, it is obvious that in a group of normal children, their speed of development during the first three years is much more significant than the relative position of an individual child within his age group. And the child's score at three years can be better predicted by the education of his parents than by his own test score obtained at any time during the first year.[22]

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[21] Jones, Conrad, and Blanchard (35) have brought out clearly the effect of rural environment on the scores made on specific tests by rural as compared with urban school children.

[22] Of course this might not be true of foster children.

IV

COMPARISON WITH OTHER INVESTIGATIONS, AND CONCLUSIONS

The results of the present study indicate that the behavior growth of the early months of infant development has little predictive relation to the later development of intelligence—even though the later behavior may depend in large part on the previously matured, elementary neural connections or behavior patterns.

It seems probable that the failure to secure high consistency correlations in test performance, even in the second and third years, can be explained by a series of shifts from one type of function to another as the children grow older. Further investigation may show that it is possible to separate the test abilities for the entire period of growth into a series of functionally different groups which, however, overlap more completely during school age than they do during the first year, and hence cannot be detected as readily. The relatively greater "constancy of the IQ" during the school ages may be due merely to the slower developmental changes, so that the tests measure very similar functions which are developing more slowly and over a longer period of years.

If this is true, we cannot measure "intelligence" before the age when the underlying sensorimotor coordinations are sufficiently matured to make possible the behavioral manifestations of intelligence. And, even then, if the intelligence measured is related to a given developmental period only, tests of it can be used for diagnosis only within the limits of that period, with the possible exception of extreme deviates such as the definitely subnormal.

These assumptions seem to be valid ones, both on the basis of the break in the standard deviation trends and the persistently low correlations between test performances at widely separated intervals. *If* there is an underlying intelligence which shows a uniform development, and is distributed among individuals in varying amounts—a "*g*" which is independent of the specific abilities measured—then these preschool tests (which are not unlike other preschool tests in the type of behavior tested) certainly do not measure it, at least during the first year, and we will have to look further for its criteria.

Although there are several investigators who claim that mental ability can be measured and predicted with fair accuracy during the first year, their methods of evaluating their data may be questioned on several counts.

Gesell, in Chapter VII of his *Infancy and Human Growth*, presents data on repeated tests of 90 infants, 80 of whom were first tested under eighteen months, to show to what extent the early scores may be considered predictive of the later. His conclusions are that: "Taken as a whole the data indicate a high degree of consistency in the course of early mental growth" (p. 148), and ". . . a rating made at four months is for predictive purposes as accurate as any rating made at any age between four and twenty-four months" (pp. 148-149).

Gesell does not, however, treat the age groups separately, nor does he take into consideration the time intervals between the tests. What is more, he does not define the limits of deviation in which a prediction may be considered to hold. Since his statistical treatment is not clear, and not that ordinarily used, it is impossible to compare his data with those of the present study, to determine the basis for the discrepancy between our conclusions. In the correlation chart (Table 9) the Intensive Growth Study data *do* show a fair consistency of performance over short time intervals, and it may be that for comparable time intervals Gesell's data would show no more consistency than these.

The same criticisms can be made of the recent study of Hallowell (28), who reports her results as in substantial agreement with Gesell's. She retested 436 children whose first tests were given between three and forty-seven months. Over 50% of the retests varied less than 5 DQ points from the first test, and very few varied more than 10 DQ points. She found, however, that the children from thirty-six to forty-seven months varied less on retests than the younger children, and that, in general, the greater the interval between tests, the less the stability. These last two findings show the same tendency as found in the present study, and would probably do so more clearly if *both* age and time interval had been controlled, since the same time interval does not represent the same increment in growth in twelve-months-old children as it does in thirty-six-months-old children.

Gesell and Hallowell have both made the mistake of using DQ's or IQ's in the first two years where the standard deviations are comparatively so very small that they do not allow a sufficiently wide range of DQ scores really to differentiate the children. With a very restricted range of scores, 50% of the children might, almost by chance alone, have retest scores that vary no more than 5 points from the earlier test. This is still more likely to be true by their method of scoring—an estimate based on all observations. Hallowell, moreover, says that it was only very rarely that she was willing to give exceptionally high or low DQ scores. In this way she has probably arbitrarily restricted her range more than an objective method of scoring would have done.

The effect of restricted range of scores on IQ may be illustrated by some of the results of the Intensive Growth Study data when scores are converted into IQ's by assigning MA's on the basis of the point score means in Table 7. The IQ range for the group at twelve months was only 35 points, while at twenty-four months, coincident with a rapidly increasing standard deviation, the range had increased to 58 points. As a result of this change, a twelve-months-old child with a sigma score of 2.98 had an IQ of only 120, while a twenty-seven-months-old child with a sigma score of 2.74 had an IQ of 133. One child at eighteen months had a sigma score of 2.32 and an IQ of 117, while at twenty-one months his sigma score had *dropped* to 2.18 and his IQ had *risen* to 121. Another child, whose sigma scores were steadily dropping between twelve and thirty months, with a range of 2.14 sigmas, changed only 8 IQ points during that time.

We cannot know until the children grow old enough to be compared with school-age children on a well-standardized scale how selected in range of ability this group is, but it is obvious over this short age range that the expression of mental or sensorimotor status in terms of an age quotient does not take care of the rapid changes in variability in young children. The small standard deviations of the early ages would automatically keep the IQ's within a small range and thus make it impossible for a child to change many IQ points between tests.

Contrary to the contentions of Gesell and of Hallowell, and in agreement with the present findings, Furfey and Muehlenbein (15) found that the scores made by children tested between six and twelve months on the Linfert-Hierholzer scale showed no relationship to the scores made by the same children on the Stanford-Binet at four years. The correlations were —.11, —.34, and —.20 respectively, for the six-, nine-, and twelve-months groups tested by Linfert and Hierholzer.

For children of preschool age the results of retests generally show a fair amount of constancy in the ratings secured, though still much greater irregularity than is found in school children. And several recent studies have shown age differences within the preschool group. Woolley (63) has found that, for nursery-school children, the younger the children tested, the greater the variation in IQ on repeated tests. Updegraff (58), on repeating Stanford-Binet or Kuhlmann-Binet tests at six-month intervals, found greater variability in the children between nineteen and forty-two months than in those between forty-three and sixty-six months. Her correlations between repeated tests did not show, in general, a high degree of consistency, ranging from .54 to .84.

Although there is general agreement that in children of school age the IQ's change very little on retests, there is some evidence that, even here, age and the time interval between tests have some effect on the constancy of the IQ. Hildreth (32), for example, in comparing intelligence measures of 441 school children who were tested from two to eight times, found a consistent decrease, with age increase, in the median IQ points change on the retest. Children from three to five years changed 1.77 points (median); from six to eight years, 1.73 points; from nine to eleven years, .59 points; and over twelve years, .42 points. She also found that when the time interval between tests was less than three years there was little variation, and when it was longer than three years there was a larger incidence of widely deviating scores. Baldwin and Stecher (1, 2) have computed correlations for as many as six repeated tests on the same children five to fourteen years of age. Though age differences have not been taken into account, there is a definite tendency for the correlation between tests to decrease as the interval between tests increases.[23]

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[23] Neither of these studies has been based on equal numbers of cases for all ages of retests, nor have age and time intervals been held con-

In general, the results of retests indicate a tendency for the constancy of mental test scores to increase with age, at least up to school age, and perhaps further. This tendency may be due, in large part, to the coincidence between decreasing increment in ability and increasing variability on the difficulty scale over which a child's performance may range. As a result of these, the same child at eight and at ten years is being tested on overlapping portions of the difficulty scale; while when the scores at one and three years are compared there is no overlapping whatever between the two test levels. And with this slower rate of maturation we may expect to find the same type of ability developing and being measured over a longer interval, even though the test items are not identical. This seems to be true when the intervals compared are in terms of absolute units rather than of chronological age (Table 10).

Retests of feebleminded children on the Stanford-Binet show greater constancy than for normal children. Whether this condition would hold, also, in the first three years of life will not be known until a sufficient number of feebleminded children are tested at these early ages. However, for this group in which there are no feebleminded infants there is no evidence from the scatter diagrams of our correlation charts that any section of the group is more consistent in its scores

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stant, so their results cannot be considered at all conclusive. The one study which does control these factors for a large number of retests, that of Hirsch (33), indicates that age and time interval do not affect the consistency of scores. His data, however, are on four different forms of the Otis Group Tests, which may not be comparable to the Binet tests used in the other studies.

than any other section. The very slow mental growth of the feebleminded, making retests include almost identically the same test items, is probably an important reason for a greater consistency of score which has been found in their retests.

In conclusion, then, we may say that mental growth (using the term "mental" to cover a series of shifting composites of performance) is very rapid during the first three years of life, and especially so during the first year. But during this early period of most rapid growth, the intelligent behavior which is observable in infants is very unlike the adult behavior which we call intelligent. The mental growth curve obtained in the present study is, then, a composite of a number of maturing functions which are successive rather than parallel; yet they overlap each other, for the most part, so that they are not separable into discrete classifications.

Since these functions are successive, the present methods of study cannot show to what extent they are influenced by training or the environment in which they mature. The low correlations between scores made during the first year and those made later force one to the conclusion that superiority in one function does not insure superiority in the subsequent development of more complex functions.

It seems evident, too, that if we are to use the word "intelligence" it must be defined either as a very general, inclusive term, of little significance until appropriate subdivisions can be made; or else it must be defined with a very restricted meaning, including only a few closely related functions, and applicable only to restricted age limits. Possibly there is a general intelligence, a "*g*" which matures with a steady, predetermined rate, from birth to maturity, and a refined method of infant testing might disclose it. But a study of the readily observable coordinations and adaptations of infants lends no support to this theory. Rather, the indications are that we have measured, at successive ages, varying composites of more or less independent functions; not until after the age of two years do these composites exhibit a significant degree of overlapping with the aggregations of traits constituting "intelligence."

V

SUMMARY

1. A graded series of tests of mental development (including approximately two hundred scored items) was given to a group of normal infants at short intervals from birth through three years. The initial sample included 61 infants. Forty-nine of these completed the third year of tests. The reliability of the tests during the first three months is not satisfactory, but from month 4 on the reliability coefficients by the split-half method, with the Spearman-Brown correction, average .86. When the tests were scaled by the Thurstone absolute scaling method, growth was found to be very rapid, being positively accelerated at first, with a deceleration in rate after about ten or eleven months. After fifteen months the rate is almost constant.

2. The standard deviations of raw scores are very small at first, showing, in general, a tendency to increase with age. The one exception to this tendency, a sharp decrease between six and twelve months, coincides with other evidence which indicates a change in the functions measured before and after this period.

The variability of the group increased, generally, with growth. The children became increasingly unlike each other in total scores and in the age at which they passed any given item. Also, as they grew older, the individual children became more variable in the difficulty-range of their successes at any one age level.

3. There is no consistency in the children's test scores over long time intervals, though scores of adjacent tests correlate fairly well. The longer the time interval between any two tests, the lower the correlation. There is, however, a tendency for scores to become more consistent as the children grow older.

4. The findings show that the tests are measuring different functions, or groups of functions, at successive age levels, rather than, as has been often supposed, a unit function of intelligence which extends throughout life. These differences are evidenced in the results of item analysis, in the directional change in the standard deviation curve, and in the low correlations over long time intervals. Development during the first six or eight months is largely sensorimotor in nature, and the more truly adaptive behavior is measured by the tests only after this period. A selection of half of the tests, through fifteen months, which seemed to be more truly "mental," gave no greater consistency in scores than did the discarded half. Probably changes in the nature of the abilities tested continue throughout the entire period, but they are not so abrupt as between six and twelve months. The decreasing rate of growth with the increasing variability of performance would tend to obliterate evidences of change in the abilities measured after the first year.

5. Some conditions which might affect the scores were considered. The correlation between scores and education of the parents is negative in the first seven months, then becomes zero, and in the second year grows increasingly positive, remaining in the third

year between .41 and .50. This trend may be due, in part, to environmental influences, but is probably mainly a result of the changing nature of the abilities tested, and possibly also of differing rates of development. The experience of the play school seems, on the average, to raise slightly the scores of the sixteen children who had play-school experience. The effect of environment on scores cannot be determined from the parent-child relationships studied here, because the developing abilities measured in the first year or two of life are different from the subsequently developed intellectual abilities which may be related to parental education.

There was no evidence for a general factor of intelligence during the first three years, but the findings indicate, instead, a series of developing functions, or groups of functions, each growing out of, but not necessarily correlated with, previously matured behavior patterns.

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LA CROISSANCE MENTALE PENDANT LES TROIS PREMIERS ANS: UNE ÉTUDE DU DÉVELOPPEMENT DE SOIXANTE-ET-UN ENFANTS AU MOYEN DE TESTS RÉPÉTÉS

(Résumé)

On a fait subir des tests mentaux à un groupe d'enfants normaux à de courts intervalles pendant les trois ans suivant la naissance. Le premier échantillonnage a compris 61 enfants. Quarante-neuf d'entre eux ont complété le troisième an des tests. La constance des tests pendant les trois premiers mois n'est pas satisfaisante, mais après le troisième mois les coefficients de constance obtenus par la méthode "split-half," avec la correction Spearman-Brown, ont donné une moyenne de 0,86. La méthode Thurstone de l'échelle absolue indique que la croissance est très rapide, étant accélérée positivement au commencement, avec une perte de vitesse après environ dix ou onze mois. Après quinze mois la vitesse est à peu près constante.

Les écarts étalons des résultats bruts sont d'abord très petits, mais s'accroissent avec l'âge. La seule exception à cette tendance, une grande décroissance entre six et douze mois, s'accorde avec d'autres témoignages qui indique un changement dans les fonctions mesurées avant et après cette période.

La variabilité du groupe s'est accrue en général avec la croissance. Les enfants sont devenus constamment différents les uns des autres à l'égard des résultats totaux et de l'âge auquel ils ont réussi à une partie donnée des tests. En outre, comme ils sont devenus plus âgés, les enfants individuels sont devenus plus variables dans l'étendue de la difficulté de leurs succès à un niveau d'âge quelconque.

Bien que les tests voisins donnent une assez bonne corrélation, avec de longs intervalles de temps entre les tests, les corrélations deviennent très peu élevées. Cependant, les résultats tendent à devenir plus constants comme les enfants deviennent plus âgés.

Les tests mesurent diverses fonctions, ou groupes de fonctions à des niveaux d'âge successifs, plutôt que quelque fonction unitaire de l'intelligence. On montre cela par l'analyse des parties des tests, le changement de direction de la courbe de l'écart étalon, et les corrélations peu élevées pendant de longs intervalles de temps. Le développement pendant les six ou huit premiers mois est principalement sensoriel-moteur en nature, et le comportement vraiment celui d'adaptation n'est mesuré par les tests qu'après cette période. Une sélection de la moitié des tests, pendant 15 mois, lesquels semblaient être les plus "mentaux," n'a pas donné une plus grande constance des résultats que la moitié écartée.

La corrélation entre les résultats et l'éducation des parents est négative pendant les premiers sept mois, puis devient nulle, et dans le deuxième an devient de plus en plus positive, restant, dans le troisième an, entre 0,41 et 0,50. Cette tendance peut être due en partie aux influences du milieu, mais sera principalement le résultat de la nature variante des habiletés testées, et possiblement aussi des vitesses différentes du développement. L'expérience de l'école de récréation semble en moyenne rendre un peu plus élevés les résultats des seize enfants qui ont eu de l'expérience dans l'école de récréation. On ne peut déterminer l'effet du milieu sur les résultats d'après ces résultats.

Les résultats des tests indiquent des facteurs globaux avec nul facteur général d'intelligence pendant les trois premiers ans.

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DAS GEISTIGE WACHSTUM WÄHREND DER ERSTEN DREI LEBENSJAHREN: EINE UNTERSUCHUNG DER ENTWICKLUNG AN 61 KINDERN MIT WIEDERHOLTEN PRÜFUNGEN

(Referat)

Es wurde eine Gruppe von normalen Kleinkindern von der Geburt bis zu drei Jahren wiederholten Intelligenzprüfungen unterworfen. Die Anfangsprüfung wurde an 61 Kleinkindern ausgeführt. 49 von ihnen vollendeten das dritte Jahr der Prüfungen. Die Zuverlässigkeit der Prüfungen war während der ersten drei Monaten nicht zufriedenstellend. Nach dem dritten Monat, aber, betrugen die Zuverlässigkeitskoeffizienten, nach der Methode der gespalteten Hälften [split-half method] berechnet, mit der Korrektur von Spearman-Brown, durchschnittlich .86. Die Thurstone'sche Methode der absoluten Rangordnung [absolute scaling] weist darauf hin, dass das Wachstum sehr rasch vorgeht. Zuerst zeigt es eine positive Beschleunigung [positive acceleration]; nach ungefähr zehn oder elf Monaten findet dann eine Verlangsamung des Wachstums statt. Nach fünfzehn Monaten ist die Schnelligkeit fast konstant.

Die Normalabweichungen der rohen Zahlen [raw scores] sind zuerst sehr klein, nehmen aber mit zunehmendem Alter zu. Die einzige Ausnahme in Bezug auf diese Tendenz bildet eine scharfe Abnahme zwischen sechs und zwölf Monaten. Diese Ausnahme stimmt mit weiteren Beweisen überein, die auf eine Änderung in den gemessenen Funktionen vor und nach dieser Periode hiweisen.

Die Variabilität der Gruppe nahm im Allgmeinen mit dem Wachstum zu. Die Kinder wurden einander zunehmend unähnlicher in Bezug auf die erzielten Gesamtzahlen und in Bezug auf das Alter in dem sie irgend einen bestimmten Gegenstand der Untersuchung zum ersten Mal bemeisterten. Ferner wurden die Kinder mit zunehmendem Alter variabler in Bezug auf den Umfang der Schwierigkeit der in einem bestimmten Alter bemeisterten Aufgaben [*difficulty-range of their successes at any one age level*].

Obwohl einander zeitlich naheliegende Prüfungen ziemlich hohe Korrelationen liefern, werden die Korrelationen, wenn die Zeitabstände zwischen den Prüfungen lang sind, sehr niedrig. Die erzielten Zahlen neigen aber dazu, mit zunehmendem Alter der Kinder näher übereinzustimmen.

Durch die Tests werden eher verschiedene Tätigkeiten [functions] oder Tätigkeitsgruppen bei Kindern in verschiedenen Altersgruppen als irgend eine einheitliche Funktion [unit function] der Intelligenz gemessen. Diese Tatsache wird bewiesen durch eine Analyse der einzelnen Testbestandteile, durch die Änderung in der Richtung Kurve der der Normalabweichungen [directional change in the standard deviation curve] und durch die bei langen Zeitabstanden [long time intervals] erhaltenen niedrigen Korrelationen. Die Entwicklung während der ersten sechs oder acht Monaten ist grossenteils sensoriell-motorischer Art, und die mehr echte Anpassungstätigkeit [adaptive behavior] wird nur nach Verlauf dieser Periode durch die Tests gemessen. Die mit einer Auswahl einer Hälfte der Tests, bis durch 15 Monaten, welche mehr echt "geistige" Fähigkeiten zu prüfen schienen, als die andere Hälfte, erzielten Resultate lieferten Zahlen, die nicht konsequenter waren, als die mit der anderen Hälfte erhaltenen.

Die Korrelation zwischen den erzielten Zahlen [scores] und der Bildung der Eltern ist in den ersten sieben Monaten negativ, wird dann Nul, wird während des zweiten Lebensjahres zunehmend positiv, und bleibt, im dritten

Jahr, zwischen .41 und .50. Diese Richtung wird vielleicht teilweise durch Einwirkungen der Umgebung bedingt, ist aber wahrscheinlich grossenteils die Folge der Änderung in der Art der geprüften Fähigkeiten und vielleicht teilweise auch von Unterschieden in der Schnelligkeit der Entwicklung bedingt. Erfahrung in einer Spielschule [play school] scheint durchschnittlich die, durch die Kinder die diese Erfahrung hatten, erzielten Zahlen etwas erhöht zu haben. Die Einwirkung der Umgebung auf diese Zahlen kann aus diesen Befunden nicht ermittelt werden.

Die Testbefunde weisen darauf hin, dass während der ersten drei Jahren eine Einwirkung von Gruppen von Eigenschaften [group factors], aber keine allgemeine Einwirkung der Intelligenz als Einheit [general factor of intelligence] stattfindet.

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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

A STUDY OF TRIPLETS

INCLUDING THEORIES OF THEIR POSSIBLE GENETIC RELATIONSHIPS*

From the Child Guidance Clinic of Los Angeles and Pasadena and the Department of Psychology of the University of Southern California

BY

FORREST N. ANDERSON

AND

NORMA V. SCHEIDEMANN

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PREFACE

Interest in a set of triplets, commonly considered identical, initiated this study. Soon attention was called to other triplets and, by including them in an investigation, the writers became involved in a rather extended and detailed study. Approaches from medical, neuropsychiatric, psychological, and educational angles were supplemented by the work of specialists in the fields of dentistry, handwriting, and the Bertillon system of finger-printing.

The main purpose of this study is to present data of three essentially normal sets of triplets representing a progressive series of similarity. A secondary purpose is to present some theories in regard to possible genetic relationships among triplets.

The writers are indebted to the following individuals for portions of the study:

To John E. Eames, D.D.S., for the examination and comparison of the teeth of one set of triplets.

To F. C. Williams, Lieutenant of the Glendale, California, Police Department, Bertillon specialist, for the portion of the study pertaining to the recording and interpreting of finger-prints.

To J. Clark Sellers, examiner and photographer of suspected and disputed documents, for the portion of the study pertaining to the photographing and interpreting of handwriting.

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The writers are especially indebted to the triplets themselves, to William, Howard, and John Hertel, to Raymond, Robert, and William Lovell, as well as to the D triplets, whose cheerful willingness to cooperate in an endless amount of tedious testing and examining made this study possible.

FORREST N. ANDERSON
NORMA V. SCHEIDEMANN

LOS ANGELES
CALIFORNIA

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I

SUMMARIES OF THREE GENERAL TYPES OF TRIPLETS

In order to study similarities and differences among triplets, three commonly recognized types were selected, namely, a set commonly considered identical, a set commonly considered to have two identicals and one sibling, and a set comprised of three siblings. The discovery of an identical set, which would be the most difficult task, was not an outgrowth of this study, but rather initiated it. Of the seven additional sets to which the writers had access, only two sets were studied since a statistical study was not planned. Summaries of the sets selected are as follows:

Set I—The H Triplets. The H triplets are 19-year-old boys, very much alike in personal appearance, mannerisms, dispositions, and habits. They seem identical in the matter of hair color, hair texture, eye color, stature, and facial features. Each has slightly malformed teeth and each has a defect in speech akin to lisping. They grew up in Kansas and while there all had straight hair. About six years ago they came to California and soon each one's hair began to show a decided wave until now each has a natural wave resembling a Marcel. The mother reports that there was but one placenta at the time of delivery.

Set II—The Los Angeles Triplets. The Los Angeles triplets, so named by the Los Angeles mayor because they were the first triplets born in Los Angeles, are 16-year-old-boys. Two boys are brunette and are practically indistinguishable from each other, while the third boy is a blond and does not look as much like his triplet brothers as he does like his older sister. In jest the brunettes are often called twins and the blond is called the triplet. The mother reports that there was but one placenta.

Set III—The D Triplets. The set of D triplets is comprised of two boys and one girl, 21 years of age. When babies, these children looked very much alike, but by the time they were five years of age they were no more alike than were their four older brothers, or than they were like their older brothers. The two boys were never of the same height or weight. Their interests have always been different. As long as the mother selected the children's clothing the boys were dressed alike and the girl had many articles of clothing like the boys', such as sweaters, caps, skirts of the same material as the boys' trousers, with blouse and tie like those of her triplet brothers. As soon as the children selected their own clothing they showed individual tastes and have never once chosen the same styles or patterns. Each child always had his own friends and playmates. The girl goes out just as much with her four other brothers as with either of her two triplet brothers. No two of the triplets seem to be together more than any two siblings, nor are the three triplets together more than any three siblings. Many teachers who taught the children several years did not know that the children were triplets. The physician in attendance at the time the children arrived reports that there were two placentae; one for one of the boys and the girl, and a separate one for the second boy.

II

THE H TRIPLETS

Personal History

J. H., W. H., and H. H., triplets, were born August 11, 1911, in the order named. No diagnosis had been made or suspected of multiple pregnancy. Normal delivery at full term; born about five minutes apart. One placenta. Weights—6½ lbs.; 5 lbs.; 4¾ lbs. The children were wanted; mother says, "We wanted a boy so badly we thought we were very lucky." Mother thinks she knew them apart from outset but, in spite of that, care was always taken to have their respective colors attached by ribbon, blanket, and the like. Everyone else always had difficulty identifying them as individuals.

As babies they cried very little; they were never held. H. was "sickly," following weaning from breast, which had to be done for all three at 6 weeks because of incessant time demands made upon mother. Many food combinations were found unsatisfactory; finally H. was placed on diluted cow's cream. Others made transition to cow's milk easily. At three months all were "overcome with gas"; no serious after-effects. Bad colds from time to time, frequent and usually simultaneous with the three; chicken pox at same time; only J. had mumps.

Teething occurred at 7 months in J. and W.; slightly later in H.; walking and talking started at 14 to 15

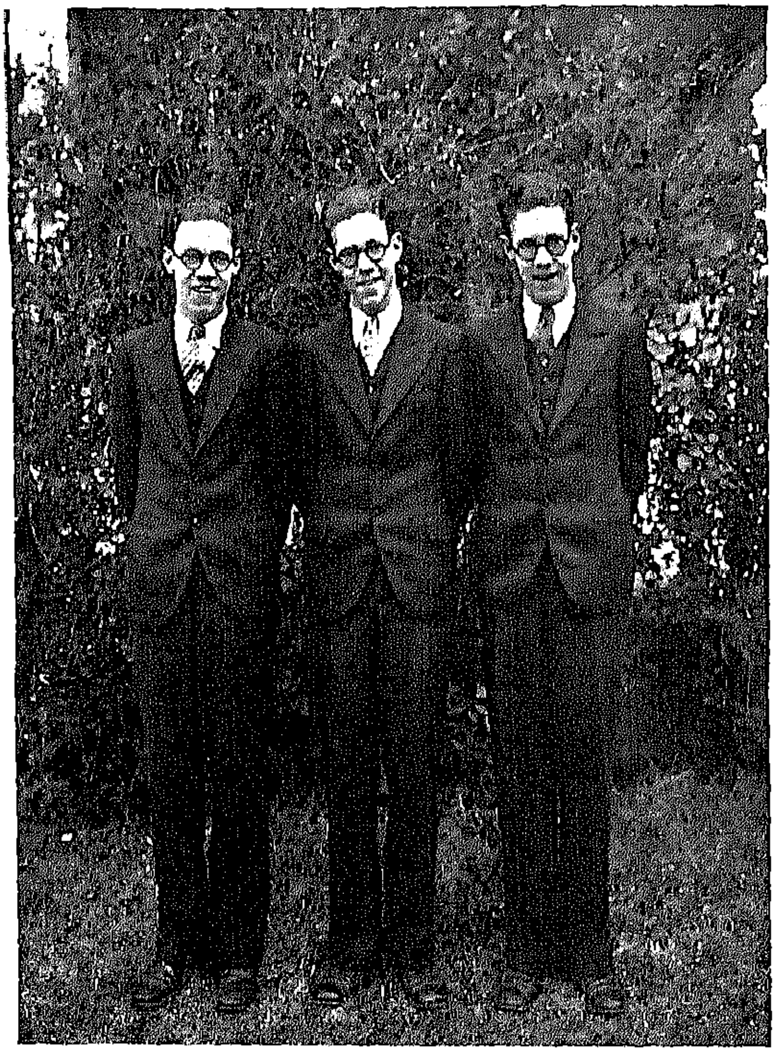


FIGURE 1

THE H TRIPLETS AT NINETEEN YEARS OF AGE

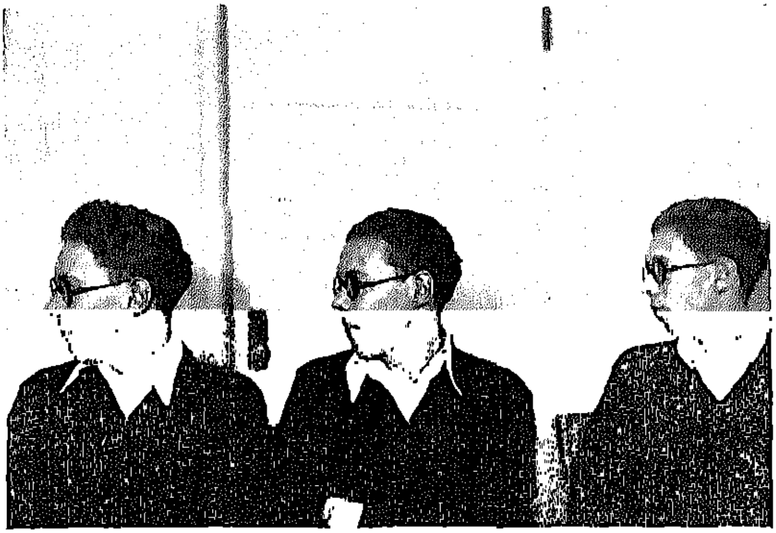


FIGURE 2

The H Triplets at Nineteen Years of Age—Profile View

months in J. and W.; again slightly later in H. All have had the same moderately projecting canines; J. had one of these extracted following an injury. All wear glasses; J. at 9; W. and H. at about 12.

There has been a noticeable lack of differences in dietary likes and dislikes. No thumb-sucking; no enuresis. When one child was separated for a short time the others would be lonesome and disconsolate; *there have been no lengthy separations. All have been* extremely close to home; have liked the same things; always have worked and planned together; always spoke as "we." They have never, until lately, been out alone much. They have liked the same girls; recently have begun to evince interest in "dates." Danc-

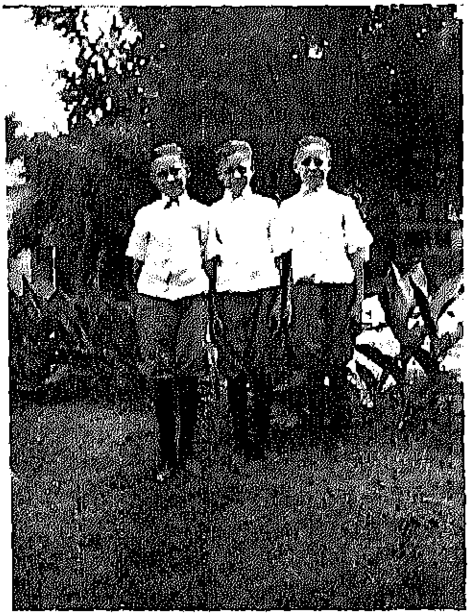


FIGURE 3
The H Triplet at Eleven Years of Age

ing school was attended at age 10; all learned equally well.

School life commenced at 5. When in the fourth grade they were given a reading test; they rated respectively in the seventh, seventh, and sixth grades. When in junior high school, the principal suggested that, since their minds were so much alike, it would be better to place the triplets in separate rooms; from that time on they have been variously in the same or in different classes. "If one halts for a word the others fall over themselves to supply it," says the mother, "they are always talking and answering."

Their best friends have great difficulty in distinguishing the triplets. This situation has been utilized by the triplets only slightly for they have had strict ideas of ethical behavior inculcated. All are great readers, liking the same books. They show great interest in movies and a very great interest in sports. In the field of sports they can carry on a most spirited conversation. Their sleeping habits are essentially similar, except that of late H. has been easier to arouse in the morning. As they have grown up, clothing and shoes have been worn out in the same general ways.

The triplets submitted to an extensive program of examinations and tests. Summaries of findings are presented without amplifications. The physical measurements of the head were made with calipers; other measurements were made with steel tape.

Neurological examinations disclosed an apparently identical normal status of the reflexes, and sensory and motor systems. Ophthalmological examinations disclosed lengthening of the eyeball of approximately the the same degrees in J. and H. There was a somewhat less lengthening of W.'s eyeball. However, adequate study of W.'s right disc, for some unknown reason, was impossible.

PHYSICAL MEASUREMENTS AND EXAMINATIONS

Results of physical measurements and examinations are given in Table 1.

PERSONALITY

The triplets responded to a personality study comprised of 41 items. The following questions are typi-

TABLE 1

PHYSICAL MEASUREMENTS AND EXAMINATIONS OF H TRIPLETS

Measurement	J	W	H
1. Height	168.27 cm.	168.65 cm.	167.0 cm.
2. Weight	55.9 kg.	57.3 kg.	56.4 kg.
3. Head circumference	56.5 cm.	57 cm.	56.75 cm.
4. Glabella-inion (over vertex)	34.0 cm.	34.0 cm.	34.0 cm.
5. Antero-posterior head	20.3 cm.	20.2 cm.	20.1 cm.
6. Biaural	13.7 cm.	13.9 cm.	13.7 cm.
7. Bitemporal	10.8 cm.	11.0 cm.	11.0 cm.
8. Jaw angle	10.1 cm.	10.3 cm.	10.2 cm.
9. Right ear	6.3 cm.	6.2 cm.	6.2 cm.
10. Forearm	42 cm.	44 cm.	42 cm.
11. Cervical prominens-acromion R.	19.0 cm.	19.0 cm.	19.0 cm.
L.	18.5 cm.	19.0 cm.	19.0 cm.
12. Right hand	22.0 cm.	22.0 cm.	20.5 cm.
13. Left hand	21.5 cm.	21.25 cm.	21.5 cm.
14. Left thumb	4.0 cm.	4.0 cm.	4.0 cm.
15. Chest circumference	80.0 cm.	81.5 cm.	81.5 cm.
16. Waist	66.5 cm.	67.0 cm.	68.0 cm.
17. Hips	84.5 cm.	83.5 cm.	85.5 cm.
18. Foot	26.0 cm.	25.5 cm.	25.5 cm.
19. Min.-max. on respiration	79-84.5 cm.	81-85.5 cm.	81-85 cm.
20 Pupil diameter	R. 4 mm.	4 mm.	4.5 mm.
	L. 5 mm.	4 mm.	4.5 mm.
21. Pulse (prone)	72	66	68
22. Pulse (exercise)	96	88	96
23. Blood pressure (prone)	126-74 mm.	124-70 mm.	116-64 mm.
24. Blood pressure (sitting)	134-74 mm.	122-68 mm.	118-60 mm
25. Blood pressure (exercise)	126-66 mm.	122-66 mm.	122-58 mm.
26. Handedness	right	right	left
27. Hair	dark brown	identical	identical
28. Skin	brownish	identical	identical
29. Marks (blemishes)	none	none	small patch freckles r. med. thigh
30. Eye pigmentation	grey blue	identical	identical
31. Ophthalmological findings	R. 7 D L. 5 D	R. 7 2D	R. 5 D L. 5 D
32. Pubic hair	plus plus	plus plus	plus plus
33. Axillary hair	plus	plus	plus
34. Genitals	well developed	well developed	well developed

TABLE 1 (*continued*)

Measurement	J	W	H
35. Chest	mild Harrison groove	normal	slight left breast enlargment
36. Reflexes	brisk and equal	identical	identical
37. Perspiration	warm moist	identical	identical
38. Heart and lungs	negative	negative	negative
39. Sensation	normal to all tests	identical	identical
40. Cranial nerves	all negative	identical	identical

cal of this study: *Are you talkative? Bashful? Sociable? Kindhearted? Tactless? Stubborn? Frank? Self-assertive? Vain? Generous? Proud? Superstitious?* The triplets' answers, given privately, were identical in 35 cases. In two cases J. claimed to differ from his two brothers; in one case W. claimed difference; in three cases one or two brothers give both positive and negative answers upon reflection.

EMOTIONAL STABILITY

The Woodworth-Cady Emotionality Test as adapted by Terman (28) was given to the H triplets. To all but five questions the triplets answered in identical terms that were indicative of stability. In the five cases where there was non-agreement, J. differed twice from his brothers; H. differed three times.

PSYCHIATRIC TEST FINDINGS

A psychiatric examination, made individually, disclosed a great similarity among the triplets, but slight differences were encountered also. When asked whether he felt that any discrimination was made among them, J. answered, "No. Being number one gave me some advantage. I thought I was the oldest when we were small; the boys always asked me what to do, and so on." To the same question, W. responded, "No. I never had any feeling on that. Oh, in a way I did feel a little sense of discrimination, for instance if we went driving J. always wanted to be first. He'd say 'I was born first.' " H. answered, "I used to feel slightly irritated in being number three; not any more though. I was sort of the baby of the family, but I think I've proved myself up to the rest. I haven't any real feeling like that now."

When spontaneous comments on differences and similarities were called for, J. said, "I think we like different kinds of girls since the girls we go with are altogether different." W. said, "Well, I think I'm a little more kind-hearted or generous. The others are not tight, but when I get paid I take the car down and get it greased; J. wouldn't think of that." H. answered, "I don't like to sit around. I like to be up and doing. The other two like to sit around more; they are not quite as active. It is quite a coincidence, but the girls we are going with are very close friends. They're different, though. When we look at anything we always remark the same things. A friend to one is a friend to all."

J. thought that the sleeping habits of the three boys were the same, except that H. might get up a little earlier. W. thought he slept the most soundly, while H. claimed to be a light sleeper. "The other two are harder to get up," said H., "J. especially is awful hard to get up." Pubertal changes were believed to have occurred simultaneously.

During the course of the examination and several other contacts, the examiner could never get away from a very strong sense of identity. Ways of responding, gestures, hesitations, general mannerisms, all left the examiner unable to keep clearly differentiated pictures of the three in mind.

INTELLIGENCE RATINGS

The registrar of the high school attended by the boys gave the intelligence quotients shown in Table 2 for the triplets as determined by the Terman Group Test of Mental Ability taken on the dates specified.

The ratings made by these triplets on the Terman group intelligence tests are of interest for several reasons. The triplets are all of normal intelligence (within range IQ 90-110); there is a remarkable adherence to the median of the normal range; on retests after an interval of about three years approximately the same IQ ratings were made; even the non-significant differences are not uniformly in favor of, or against, any

TABLE 2

TERMAN IQ's OF H TRIPLETS

	Date	Test	IQ
H	10-27-'26	Terman Form B	99
	12-11-'29	" " B	105
J	10-27-'26	" " B	104
	12- 3-'29	" " A	100
W	10-27-'26	" " B	102
	4- 4-'29	" " A	99

TABLE 3

OTIS DATA ON H TRIPLETS

	Score on Otis S.-A.	Age norm 18 yrs. or over	Binet MA equivalents of scores	Corresponding Alpha score	Otis IQ
H	49	42	16-5	131	107
J	50	42	16-6	137	108
W	47	42	16-2	129	105

particular triplet; the ratings were not influenced by a particular form of the test.

The Higher Examination, Form A, of the Otis Self-Administering Tests of Mental Ability (30-minute time limit) was given to these boys by one of the present examiners. Table 3 gives the data obtained from this examination.

The ratings on the Otis examination indicate a remarkable similarity in mental ability, and a very close adherence to the norm for adults. The slightly higher IQ ratings obtained on the Otis examination in comparison with those obtained on the Binet scale (older students) may be due to Otis's method of obtaining IQ's. Otis believes that the method he provides gives IQ's that correspond with what the Binet IQ's of older students were when they were younger.

VOCABULARY RATINGS

Terman emphasizes the significance of vocabulary tests. He found the correlation of the vocabulary test in the Stanford Revision with the entire scale to be .91 for school children and .81 for adults. Mental age based upon vocabulary score alone, he says, would not be far wrong in a large percentage of cases.

On the Stanford Revision vocabulary test, this set of triplets rated as follows:

W.	11,520 words	(average adult vocabulary)
J.	11,160 words	(average adult vocabulary)
H.	11,880 words	(average adult vocabulary)

All three boys passed the first 21 words and failed on the last 10 words (one list only was used). The 18

TABLE 4

TRANSCRIPT OF SCHOOL RECORDS OF H TRIPLETS

Subjects	J.	W.	H.	
English 1	C/B	C/D	B	
2	3+	3+	B/5	H.'s 5 made up with a 2
3	3+	3+	3+	
History				
Ancient	C/B	C/B	C/A	
Modern	2	3+	3	
U. S.	3	3+	3+	
Civics	3	3	3+	
Economics	3+			
Soc. Prov.		3+	3+	
Algebra	A/3	B/3		
Biol. lab.	3+	3+	3+	J., W., and H. failed Biol. lab. Each repeated the course, making grades of 3+.
Chem. lab.	3/B			
Physiology		2	3+	
Typing	4/B			J. failed typing in second sem. and repeated it, making a grade of B.
Advertising	C	C	B	
F. H. drawing	C/B	C/B	C/B	
Woodwork	2	3+	B	
Music	B	B	B	
Phys. Educ.	A	A		
Oral English	B/C	B/C	B/C	
Adv. F. H. draw.	3	3+	3+	
Auto shop	C	C	C	
Printing		B		

Passing grade in school 3/D.
Grade required for recommendation to college 2/B.

intermediate words showed irregular successes and failures for the three boys.

SCHOOL RECORDS

Transcripts of the H triplets' tenth-, eleventh-, and twelfth-grade records are given in Table 4.

INTERVIEWS WITH INSTRUCTORS WHO TAUGHT ALL THREE OF THE H TRIPLETS

Mr. R.—Auto shop

"I had them two years; I had to give them the same grade simply because I could not tell them apart. I did not feel they had especial mechanical ability. They got on all right with the other fellows. They were especially enthusiastic over the physical education department."

Mr. G.—Woodwork

"Nicer boys I never had as far as willingness to do is concerned; you couldn't tell them apart. I had H. two years and W. one year. H. was a boy you could train to almost anything; I think he was the quicker of the two in an emergency. H. did some beautiful cabinet work. Of course I knew more about him."

Mr. T.—Advertising

"I found there was a remarkable similarity in what I call degree of responsibility and efficiency among the boys. The only difference I could mention was that H. was a little more reliable and steadier than the other two. Possibly W. was a little flightier—more apt to be talkative and excited over school affairs. H. was a bit more interested in this class and has plans along this line. During the last part of the course I could tell them apart. They had happy and rather volatile dispositions—almost effervescent. I noted no changes in mood. They were generally popular; all three 'fell' for the same girl in the class. Their work was remarkably uniform."

Mrs. T.—Cafeteria Manager

"By getting the three lined up together I could tell them apart. One was noticeably quieter; I don't know if it was W. or H. They were nice chaps, always very courteous and thoughtful. They were dependable, and very popular."

TABLE 5

MECHANICAL APTITUDE RATINGS OF H TRIPLETS

Test	J.	W.	H.
MacQuarrie	51 (low)	49 (low)	47 (low)
Stenquist (raw scores)	85	70	75

MECHANICAL APTITUDE RATINGS

Two tests designed to measure mechanical aptitude, the Stenquist Assembly Test, Series II, and the MacQuarrie Test for Mechanical Ability, were given to the H triplets. The scores attained are shown in Table 5.

The Stenquist test is comprised of a series of 10 assembly tests each consisting of a common mechanical object. Each mechanical model is presented unassembled and the subject is required to assemble it under standard conditions. The MacQuarrie test is a paper test testing component factors of mechanical ability such as recognition of space, muscular control, visual acuity, and the like. The differences in the types of the tests must be kept in mind when interpreting the scores. All three boys took courses in auto mechanics, woodwork, and shop. Possible effects of practical experience must be kept in mind also.

In an interview in regard to the boys' work in auto mechanics, the instructor of the class said that "the boys have no mechanical ability."

VISUAL ART RATINGS

Three tests of visual art, recognition of proportion, recognition of color, and originality of line drawing,

TABLE 6

VISUAL ART RATINGS OF H TRIPLETS

	J.	W.	H.
Recognition of proportion	8 (average)	6 (inferior)	5 (inferior)
Recognition of color	38 (very superior)	33 (average)	36 (superior)
Originality of line drawing	1 (inferior)	1 (inferior)	1 (inferior)

were selected from Lewernz's Tests in Fundamental Abilities of Visual Art. The first two tests are arranged in multiple-choice forms. Each of the three tests is designed to measure physical capacity or native efficiency. Success in the tests is considered to be rather independent of training.

The scores made on the art tests are as shown in Table 6.

THE KENT-ROSANOFF ASSOCIATION TEST RESPONSES

The Kent-Rosanoff Association Test was given to the H triplets and a comparison of the responses was made. Among H.'s responses there were five and among W.'s there were eight responses not found in the frequency tables based upon the responses of 1000 normal subjects. Kent and Rosanoff recognized that the frequency tables do not exhaust all normal possibilities of word reactions; some essentially normal reactions are found among individual reactions and are not to be classed as pathological. The devisers of this test proceeded to define the words that are to be counted as normal, although occurring as individual reactions. When these definitions are taken into consideration, H. showed two individual reactions and W. three. J. gave no individual responses.

J. and W. each gave one doubtful response and H. gave two. Two of W.'s three individual responses are also classed as juvenile responses. H. and J. gave no juvenile responses. None of the boys responded with neologisms, word complements, particles of speech, or gave indication of the phenomenon of perseveration. One of W.'s individual responses was an association to the preceding stimulus. None of the boys gave an association to the preceding reaction. There were no repetitions of previous stimuli, and no unclassified responses. There was no failure to respond to a stimulus word.

THE WATSON TEST OF PUBLIC OPINION

The Watson Test of Public Opinion, in reality a measurement of common deviations from fair-mindedness, was given to the H triplets when they were 19 years 8 months of age (given 4-19-'31). At this time J. was a clerk in a drug store, W. a clerk, and H. an assistant pharmacist. The three boys were then, and had been for a period of about 11 years, affiliated with the Roman Catholic church.

The gross scores made by the boys on the Watson test, the distribution of the points over the six forms (parts) of the test, together with Watson's mean score (311 cases) and standard deviation, are shown in Table 7.

TABLE 7

DATA ON THE H TRIPLETS' GROSS SCORES ON THE WATSON TEST OF PUBLIC OPINION

	Forms of test						Gross score
	A	B	C	D	E	F	
W.	21	24	36	16	12	15	25%
H.	25	84	32	14	4	33	36%
J.	21	27	28	17	8	30	27%
Watson mean	28.9	40.9	27.1	44.3	37.6	16.7	29.1
S.D.	11.5	19.8	20.5	20.8	29.9	12.5	11.3

Watson provides a method for making an analytical evaluation of the gross score, indicating the extent to which the prejudices of a subject are in agreement with the special interests of (1) economic radicals, (2) economic liberals, (3) economic capitalists, (4) persons fighting for a "social gospel," rather than an individual interpretation, (5) persons interested mainly in a "personal gospel," prayer, mysticism, communion, salvation, etc., (6) fundamentalists, orthodox "Apostles' Creed" variety, (7) modernists, holding liberal Christian views, (8) religious radicals, very broad, displeased with most existing Christian manifestations of religion, (9) Protestants who are inclined not to like Catholics, (10) Catholics who are inclined not to like Protestants, (11) persons with high, strict standards of sex-ethics, or amusement, or "bad habits," or similar moral matters, (12) persons with broad loose standards of sex-ethics, or amusement, or "bad habits," or similar moral matters.

A convenient method of representing the analytical score for an individual is by means of a prejudice pro-

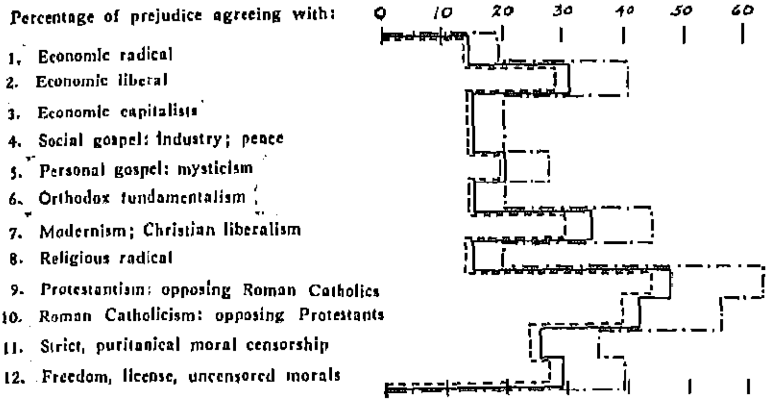


FIGURE 4

THE H TRIPLETS' PREJUDICE PROFILES ON THE WATSON TEST OF PUBLIC OPINION

———————— J.
- - - - - - - - - - - - W.
— . —. .— . — H.

file. Figure 4 represents the superimposed profiles of the H triplets in order to permit ready comparison.

VOICE

In conversation with the triplets, the investigators noted striking similarity in the triplets' voices. The pitch and quality of the voices, as well as a slight speech impediment, seemed so much alike that an experimental situation was arranged to see whether the individual voices could be distinguished.

Copies of Lincoln's Gettysburg Address were prepared in which sentences were paragraphed in irregular manner. Each paragraph was designated to be read by one triplet. Sometimes the same triplet would be required to read two or three successive paragraphs, always waiting two or three minutes between paragraphs. Seven paragraphs were assigned to each triplet. For the observers blanks were prepared on which the name of the triplet reading each paragraph could be recorded. The observer not acquainted with the boys was required to record "same" when the same triplet read a following paragraph, and "different" when another triplet read a following paragraph.

Four observers took part in the experiment; the father, the mother, a close adult friend of the triplets, and one of the investigators. The triplets were stationed at one end of a large double room, as closely together as possible (one sitting on a chair, the other two standing behind the chair so that the three heads were as close together as possible). The observers were seated at the opposite end of the room at a distance of about 15 feet from the triplets and with their backs toward the triplets.

The three observers who were well acquainted with the triplets were able to recognize which one read each of the 21 paragraphs included in the experiment. The observer who did not know the boys was able to recognize in each case whether the same or another triplet read a following paragraph.

This crude experiment did not control voice intensity, rate of reading, expression, or absolute direction of sound, factors that furnished clues for the observer not well acquainted with the boys.

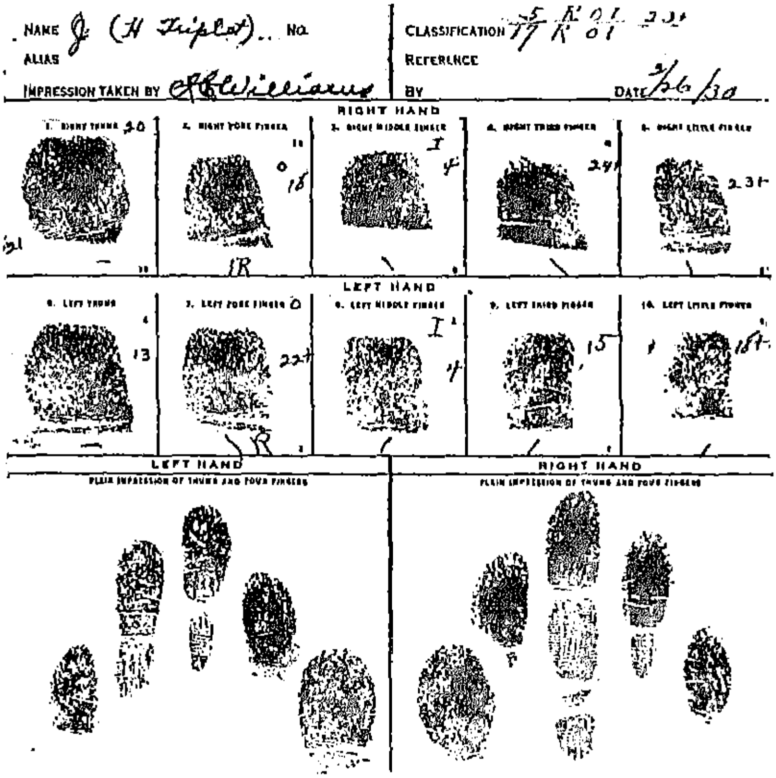
TEETH

Dr. John E. Eames examined the dental arches and the teeth of the H triplets and made the following report:

"In all three cases the eruption of the third molars is incomplete with indication of normal position and eruption. All possess great similarity.

"The contours of the arches bear close similiarity with no supernumerary or missing teeth. In each case the upper arch appears underdeveloped and slightly pointed with protruding anterior teeth.

"In each case the supporting tissue offers evidence of inflammatory disturbance with serumal deposit present around many of the teeth. This most likely has origin in dietary imbalance, and is transitory.



NAME J. (H Triplet) NO.
ALIAS
IMPRESSION TAKEN BY Williams
CLASSIFICATION 5/17 R/R 01/01 22
REFERENCE
BY
DATE 2/26/30

RIGHT HAND
1. RIGHT THUMB 20
2. RIGHT FORE FINGER 18
3. RIGHT MIDDLE FINGER I 4
4. RIGHT THIRD FINGER 24
5. RIGHT LITTLE FINGER 23
LEFT HAND
6. LEFT THUMB 13
7. LEFT FORE FINGER O 22
8. LEFT MIDDLE FINGER I 4
9. LEFT THIRD FINGER 15
10. LEFT LITTLE FINGER 18
LEFT HAND
PLAIN IMPRESSION OF THUMB AND FOUR FINGERS
RIGHT HAND
PLAIN IMPRESSION OF THUMB AND FOUR FINGERS

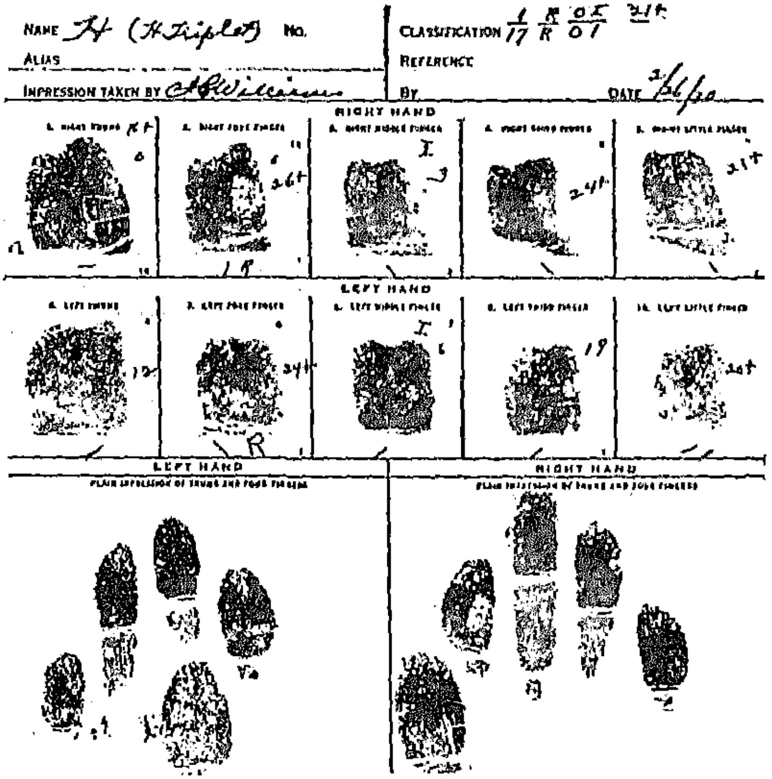
FIGURE 5
FINGER-PRINTS OF J. (H TRIPLET)
(Reduced one-half)

"Structural defects of enamel are found occasionally. Some teeth of all three boys have been filled.

"The great similarity in these three cases is the tooth form (mold) being identical."

FINGER-PRINTS

Lieutenant F. C. Williams of the Glendale Police Department took the impressions of the finger-prints



NAME H (H Triplet) NO.
ALIAS
IMPRESSION TAKEN BY CFWilliams
CLASSIFICATION 1/17 R/R OI/OI 21t
REFERENCE
BY
DATE 2/6/30

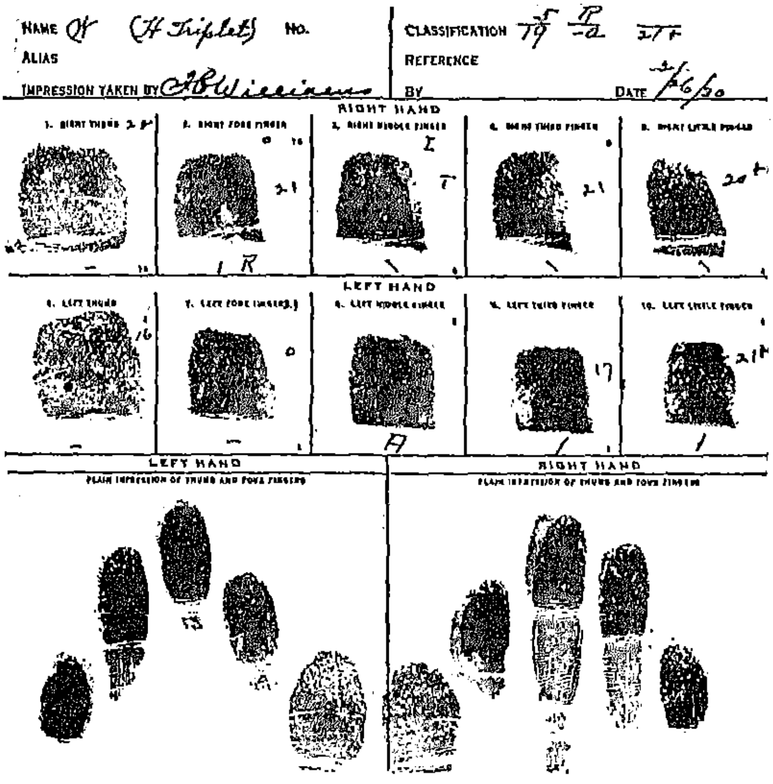
RIGHT HAND
LEFT HAND
LEFT HAND
RIGHT HAND

FIGURE 6
FINGER-PRINTS OF H. (H TRIPLET)
(Reduced one-half)

of these triplets and made an analysis of the prints. He presents the following findings:

"Although there are occasional *crude similarities* in the finger-prints of these triplets, there is not a single instance of *identity* between any two fingers. The following are some of the gross similarities and differences disclosed in a rigid examination of the total 30 finger-prints.

"W. and J. have a whorl in the right thumb of a similar pattern



NAME W (H Triplet) NO.

CLASSIFICATION

ALIAS

REFERENCE

IMPRESSION TAKEN BY

BY

DATE

FIGURE 7

Finger-Prints of W. (H Triplet)

(Reduced one-half)

but with different ridge counts, different bifurcations, different abrupt endings, and different departures of the ridges.

"There is a similarity in W.'s and H.'s right index fingers with J.'s left index finger, yet entirely different counts are found to be present in each case.

"W.'s left middle finger bears a plain arch which does not show in any of J.'s or H.'s fingers and in no other of W.'s fingers.

"In the balance of the fingers we find that W.'s right ring and right little fingers do not show similarities to H.'s or J.'s corresponding fingers.

"W.'s right forefinger bears a radial loop pattern. Likewise, radial loop patterns are found in H.'s right and left fore fingers and in J.'s right and left fore fingers, but in each pattern there is a different count and each is a different kind of radial loop pattern.

"Although these triplets may be called 'identical' and to the casual observer may seem exactly alike, it is enlightening to know that their finger-prints are noticeably not alike even to the layman.

"There are no two fingers of the total 30 digits that are in any way alike, not even in ridge counts.

"A comparison of the ridge counts is here presented in tabular form:"

TABLE 8

RIDGE COUNTS OF H TRIPLETS

	Right hand			Left hand		
	J.	W.	H.	J.	W.	R.
1. Thumb	20	22	16+†	13	16	12
2. Forefinger	*O**18	*O*21	*O*26+	*O*22+	*O*21	*O*24+
3. Middle finger	*I** 4	*I* 1	*I* 3	*I* 4		*I* 6
4. Third finger	24+	21	24+	15	17	19
5. Little finger	23+	20+	21+	18+	21+	20+

**O* stands for "outer"; *I* for "inner."

†21+ and 24+ mean indefinite counts. There are at least 21 and 24 ridges but how many more is not determined.

The "classifications" of J., W., and H. are

$$\frac{5\ \mathrm{R}\ \ \mathrm{OI}\ \ 23+}{17\ \mathrm{R}\ \ \mathrm{OI}},\quad \frac{5\ \ \mathrm{R}}{19\ -\mathrm{a}\ \ 21+},\quad \text{and}\quad \frac{1\ \ \mathrm{R}\ \ \mathrm{OI}\ \ 21+}{17\ \mathrm{R}\ \ \mathrm{OI}},$$

respectively. This does not show a greater similarity between any two than with a third.

III

THE LOS ANGELES TRIPLETS

PERSONAL HISTORY

R. L., W. L., and Ray. L., the Los Angeles triplets, were full-term babies; delivery is said to have necessitated version of the first child. A diagnosis of triplets or twins was not made. The mother states that the physician in attendance at the time of delivery reported a single placenta with three umbilical cords. The weights for R., W., and Ray., were 5 lbs., 5½ lbs., and 5¾ lbs., respectively. The children were breast-fed for three months. All had essentially negative health histories; since five years of age, there has been

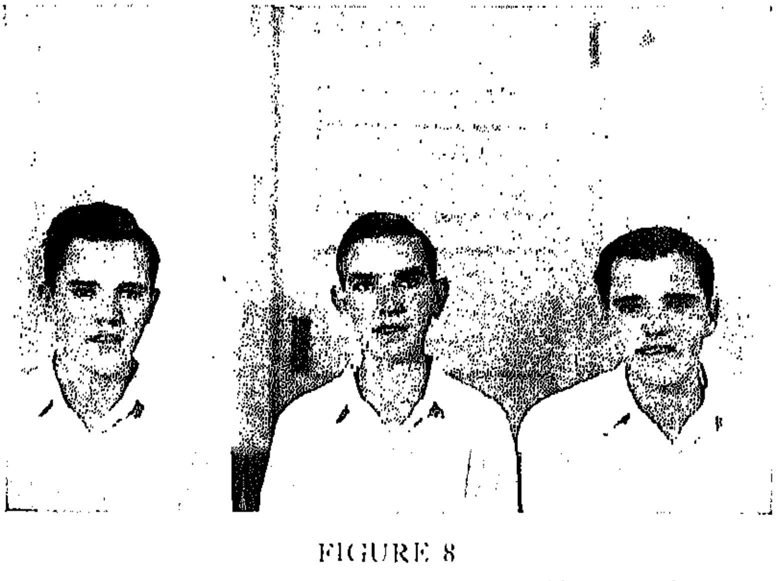


FIGURE 8

THE LOS ANGELES TRIPLETS AT SIXTEEN YEARS OF AGE

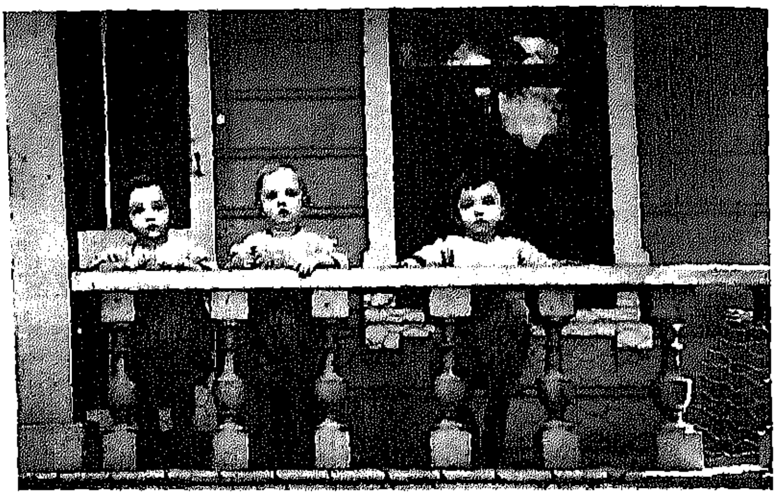


FIGURE 9
THE LOS ANGELES TRIPLETS AT EIGHTEEN MONTHS OF AGE

no particular illness. W. has had some trouble with his teeth. These triplets were born September 22, 1913.

There is no history of twinning on either side of the family. The father is 70 years of age at the time of this study and the mother is about 45 years of age. The father has greyish-blue eyes and the mother, dark eyes and hair. There are two other children in the family, a girl 20 and a girl 14 years of age.

The mother made the following statements in regard to the triplets:

"The boys were perfectly normal, healthy children from the very first. They began to walk within a few minutes of each other. One day when they were just 9 months old, W. pulled himself up at the table and began to walk around it holding on to the table top. Ray. screamed, then took hold of the table top also and toddled after

W. R. followed and all three toddled around the table holding on to the top.

"I think they were a bit slow about talking, but at 18 months they were calling 'mama.' Perhaps other things, but I am not able to recall. They always shared with each other; no matter how small a piece of candy one had, or an apple, it was shared. They still share everything, but my other children do too, as far as that goes. When they were small I could not tell which child cried, in fact I could not tell the two dark ones apart for ever so long. No one could. I can tell their speaking voices apart now. Ray.'s voice is softer. R. and W.'s voices are very much alike.

"R. never had any clothes, always wore out his things. I had to patch more for R., too. Any bad luck that occurred, R. and W. always got it. Ray. takes better care of his clothes; he has always been more careful with his clothes. Ray. wears shoes a size larger than R. and W. R. and W. can wear each other's shoes after the shoes have been worn a while.

"When, as children, the boys would get sick, they all got sick at the same time. At birth the children were about the same weight, but Ray. soon grew heavier and taller than the other two. Then Ray. was always heavier and a head or a half head taller than the other two who were always exactly the same in height and weight. When they were about 15 years of age Ray. began to be thinner and weighed less than the other two who still continued to remain the same.

"R. is more sensitive than the other two children; his disposition is totally different, he is very stubborn, you cannot convince him. W. and Ray. are more reasonable. R. does not care to meet the public; he is self-willed; you cannot lead him; occasionally I get close to him, but as a rule he is headstrong and cannot be talked to. W. and Ray. are more like I am, easily advised if convinced it is right. R. has the foolish feeling that there is some discrimination in favor of his brothers. He says, 'It's always I—why don't you ask Ray. or W.?'

"R. and W.'s teeth overlap in the same way. Ray.'s are like my oldest child's teeth. R. is right-handed in everything. Ray. and W. write with the right hand, but throw and bat with the left hand.

"R. and W. would enjoy opening an auto shop; Ray. is full of business, making money, etc. He has more the brains, the others are more plodders, work with their hands. They have all been very much united; when one was missing the others always felt something was wrong. Usually they have made and held the same friends."

Physical Examinations

Routine physical examinations are substantially negative except for W., who presents definite mitral systolic murmur. Heart appears to be slightly enlarged to percussion; no evidence of failing compensation. No adequate history of rheumatic infection obtained; cardiac defect has been noted before.

Neurological examinations negative to alterations in states of sensory, motor, reflex, or cranial nerve systems.

During all examinations the neurologist experiences strong sense of similarity between W. and R. in contrast to Ray., who is of different build throughout.

TABLE 9

Physical Measurements and Examinations of the Los Angeles Triplets

			W.	R.	Ray.
1.	Height		178 cm.	170.8 cm.	162.4 cm.
2.	Weight		61.0 kg.	61.0 kg.	54.1 kg.
3.	Head circumference		56 cm.	56 cm.	54.5 cm.
4.	Ear to ear over vertex		33 cm.	32 cm.	30 cm.
5.	Forearm		43 cm.	43 cm.	42.5 cm.
6.	Palm circumference	R.	19.5 cm.	19.0 cm.	18.0 cm.
		L.	20.0 cm.	18.5 cm.	17.5 cm.
7.	Neck circumference		33.5 cm.	33.5 cm.	30.5 cm.
8.	Chest circumference		87.0 cm.	89.0 cm.	83.0 cm.
9.	Min.-max. on respiration		86-91 cm.	88-91 cm.	82-85.5 cm.
10.	Waist		75 cm.	73 cm.	68 cm.
11.	Hip		88.5 cm.	90.0 cm.	86.0 cm.
12.	Foot		24.0 cm.	24.0 cm.	25.0 cm.
13.	Eyes		dark brown	identical	blue
14.	Hair		dark brown	identical	blond
15.	Pulse		88 (128)	92 (116)	80
16.	Blood pressure		145-100 mm.	145-90 mm.	118-85 mm.

PERSONALITY

A personality study comprised of questions such as, *Are you shy? Lively? Talkative? Sociable? Stubborn?* and the like, was given to the Los Angeles triplets. While the study was not sufficiently extensive to delineate personality or to indicate definite differences in personality, still there seemed to be a slight tendency toward a greater similarity between W. and R. than between either of these two and Ray. The examining psychiatrist noted that W. and R. gave prompt and impulsive responses, and frequently responded with "Sure"; Ray. responded more thoughtfully and rarely said "Sure."

INTELLIGENCE RATINGS

The Terman Group Test of Mental Ability, Form A, was given to the Los Angeles triplets by the Los Angeles city schools. At the time of taking the test Ray. was 12 years 9 months of age; R. and W. were 13 years 4 months when they took this test. The ratings are given in Table 10.

These ratings, made on a group test, may be considered within the range of normal intelligence (IQ 90-110). Because of the commonly questioned reliability of group tests, the value of these IQ's would not be so

TABLE 10

TERMAN IQ'S OF THE LOS ANGELES TRIPLETS

	Date	IQ
Ray.	6-25-'26	107
R.	1-13-'27	89
W.	1-13-'27	95

TABLE 11

OTIS DATA ON THE LOS ANGELES TRIPLETS

	Score on Otis S.-A.	Age norm	Binet MA equivalents of scores	Otis IQ.
Ray.	47	40	16-2	107
R.	30	40	13-3	90
W.	37	40	14-6	97

significant were it not for the fact that on the Otis Self-Administering Test of Mental Ability, Higher Examination, Form A, given by one of the present investigators, practically the same ratings were made. The results of the Otis examination, given when the boys were 16 years 6 months of age (date 3-14-'30), are presented in Table 11.

In the case of these triplets, no allowance need be made for the tendency of the Otis IQ's to be slightly higher than the Binet IQ's, because the boys were young when they were given the Terman test.

The points of interest in regard to the intelligence ratings of these triplets include the following: There is a greater similarity between R. and W. than between either of these two and Ray.; the ratings on the two tests are remarkably similar, in spite of the fact that the Terman test was given at different dates.

VOCABULARY RATINGS

On the vocabulary test of the Stanford-Binet Intelligence Scale, this set of triplets rated as follows:

Ray.	10,440 words
R.	7,920 words
W.	9,360 words

The three boys passed the first 15 words of the vocabulary test and failed on the last 14 (one list only was used). The 21 intermediate words showed irregular successes and failures for the three boys.

The average adult vocabulary is estimated to be 11,700 words (Terman) in comparison with the 10,440-word vocabulary of Ray. whose Binet mental age was estimated at 16 years 2 months (Otis test). Terman gives a vocabulary of 7,200 words as standard for 12 years and a vocabulary of 9,000 words as standard for 14 years. R. and W., having Binet mental ages of 13 years and 3 months, and 14 years 6 months, respectively, do not reach these standards. This may be explained by the limited opportunities for reading afforded in the home and by the general non-literary subjects taken by the boys in school.

MECHANICAL APTITUDE RATINGS

On the Stenquist Mechanical Aptitude Test (paper test) these triplets made the following percentile ranks:

	Percentile rank
Ray.	71
R.	71
W.	79

None of the boys professed an interest in mechanics. Since none of the boys has opportunity to manipulate machinery or mechanical apparatus of any sort, no check on the test ratings could be made. The main fact in the attained ratings is that Ray. does not retain a superiority over his brothers in this ability.

SCHOOL RECORDS

School records of all three boys were obtainable for only the grades 7A, 8, and 9, as given in Table 12. Ray.

TABLE 12

TRANSCRIPT OF SCHOOL RECORDS OF THE LOS ANGELES TRIPLETS

	Ray.	R.	W.
Grade 7A			
Cooperation	—	B	A
Effort	—	B	A
Drawing	C	B	B
English	C	C	B
Mathematics	C	D	C
Phys. educ.	B	A	A
Practical arts	A		
Agriculture		A	B
Geography	B	B	A
Grade 8			
Cooperation	A	A	A
Effort	A	B/A	A
English	B/C	B	B
Mathematics	C	C/B	B/C
Latin	/C		
Phys. educ.	B/A	A	A
Practical arts	B	B/A	A
Science	B/	A/	B/
History	A/B	A/B	A
Grade 9			
Cooperation	A	A/	A/
Effort	A	A/—	—
English	C/B	A/B	B/
Gen. science	B/A		
Jr. business training		A/B	A/
Latin	C/D		
Mathematics	C		
Oral English	/B		
Phys. educ.	A/B	A	B/
Practical arts	A/	A	A/
Mechanical dr.		C/	
Social studies		B/C	B/
Typewriting			B/

has been a year in advance of his two brothers for some time. On account of illness, R. and W. dropped out of school for a while during a semester in one of the lower grades. Ray. was promoted at the end of the semester and, on account of crowded conditions in

Ray.'s grade, double promotions were made in the case of some children, including Ray. Thus, Ray. was placed a year in advance of his brothers who were advanced only a half grade at the end of the semester. At 16 years of age, Ray. is in the eleventh grade; R. and W. are in the tenth grade.

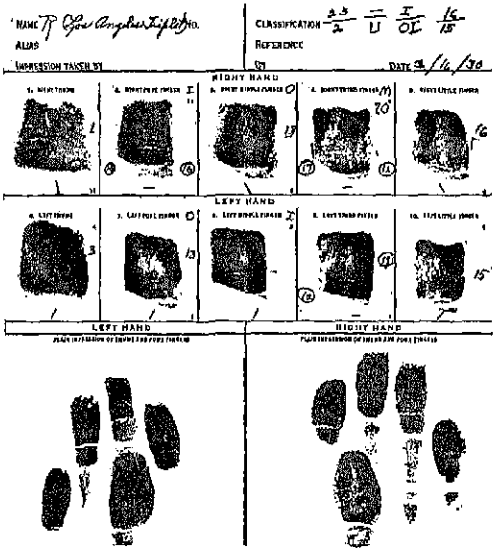
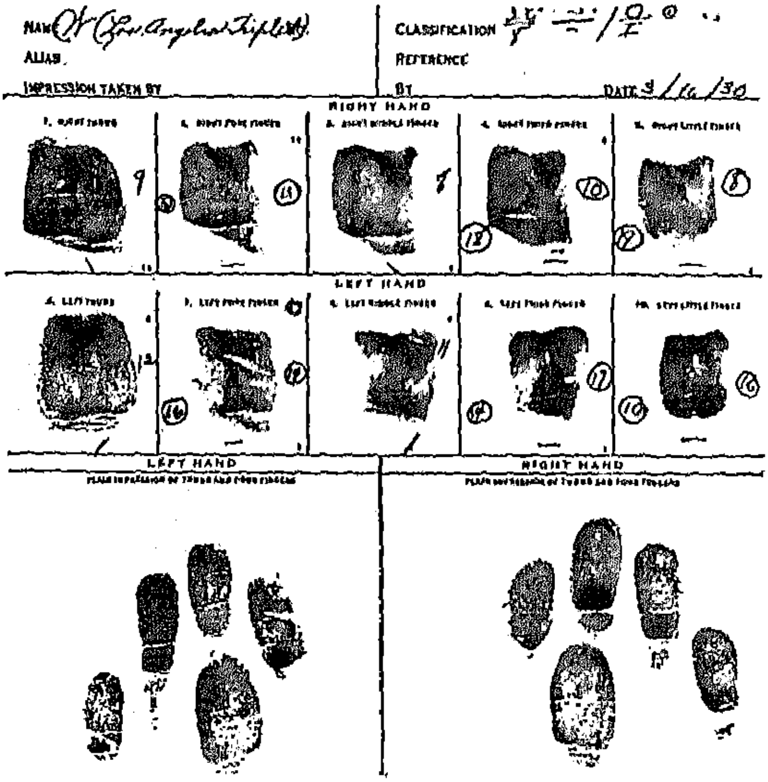


FIGURE 10
Finger-Prints of R. (Los Angeles Triplet)
(Reduced one-half)

FINGER-PRINTS

Finger-prints were made of the Los Angeles triplets by Lieutenant F. C. Williams of the Glendale, California, Police Department. These prints, together with Lieutenant Williams' interpretations, are submitted in their entirety.



NAME W (Los Angeles Triplets)
ALIAS
IMPRESSION TAKEN BY
CLASSIFICATION
REFERENCE
BY
DATE 9/16/30

RIGHT HAND
LEFT HAND
LEFT HAND
RIGHT HAND

FIGURE 11
FINGER-PRINTS OF W. (LOS ANGELES TRIPLET)
(Reduced one-half)

INTERPRETATION OF FINGER-PRINTS OF THE LOS ANGELES TRIPLETS

Made by Lieutenant F. C. Williams of the Glendale Police Department

Right Thumb:

R.: Ulner Loop with count of two.
Ray.: Whorl Meeting counts: 15 right 21 left.
W.: Perfect Loop with 9 count.

Left Thumb:

Ulner Loop all three; W. and Ray.—Similar patterns but not alike; different counts as: 12 and 7 counts.

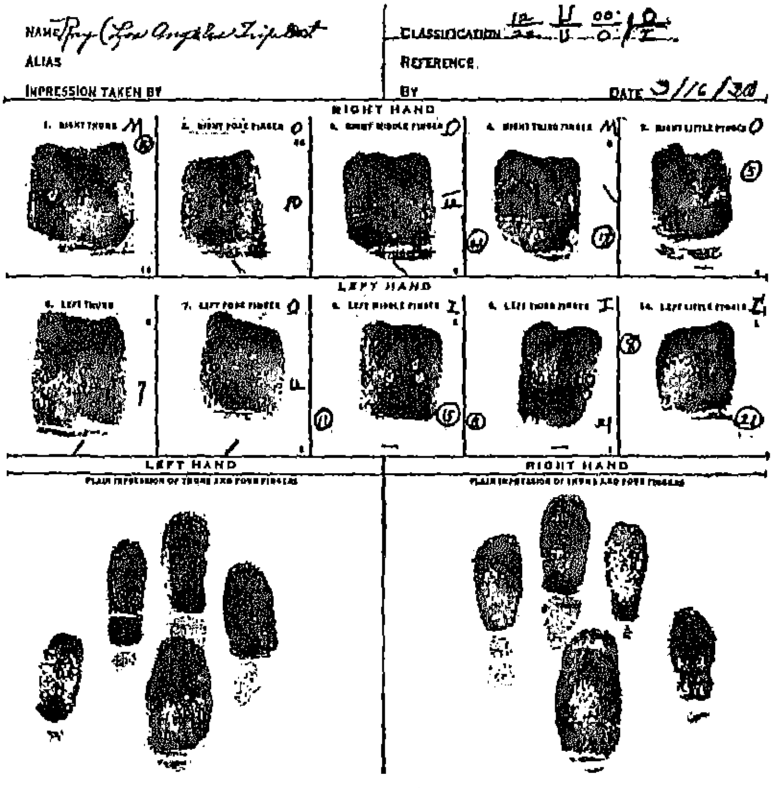


FIGURE 12
FINGER-PRINTS OF RAY. (LOS ANGELES TRIPLET)
(Reduced one-half)

Right Forefinger:

R.: Whorl Inner 16 right 10 left.

Ray.: Ulner Loop 10 count.

W.: Whorl Inner 16 right 5 left

Ridge count in Whorl decidedly different; both turn into the pattern from the same side, this being the only similarity.

Left Forefinger:

Ray. and R.: Ulner Loops decidedly different patterns.

W.: Whorl: perfect; no similarity to any other, some similarity between W.'s left forefinger and R.'s right ring finger; however there is a difference in ridge count of 3.

Right Middle Finger:

All Ulner Loops; Ray., R., and W. counts in sequence as follows 12 - 8 - 13.

Left Middle Finger:

Ray.: Whorl Inner 15 right 11 left.

W. and R.: Ulner Loops; these are noticeably different in pattern and design.

Right Ring Finger:

Whorl in each of R., Ray., W. counts in sequence as follows: Meeting 12; Meeting 17; Outer 10.

Left Ring Finger:

Whorl in each of R., Ray., W., and all Inner; there is a close resemblance between these prints in pattern accept for ridge counts which in sequence are as follows: 12 left 14 left 15 left.

Right Little Finger:

R.: Ulner Loop with 16 count.

W. and Ray.: Whorls different count as follows: 8 right and 5 right in sequence.

Left Little Finger:

W. and Ray. have Whorl patterns Inner counts in sequence as follows: 16 right and 21 right.

R. has Ulner Loop with 15 count.

F. C. W. 3/22/30.

IV

THE D TRIPLETS

PERSONAL HISTORY

C. D., W. D. (boys), and Ca.D (girl), triplets, were born in September, 1909. No diagnosis was made or suspected of multiple pregnancy. Delivery was normal at the end of the full term. Two placentae, one for one boy and one for the other boy and the girl, were reported by the physician in attendance. A girl was wanted since the parents already had four boys. Both parents came from large families; there were no twins or triplets on either side of the family.

As children, the triplets were always healthy. They had only minor illnesses and recovered rapidly. Weights and lengths at birth were as follows (Table 13):

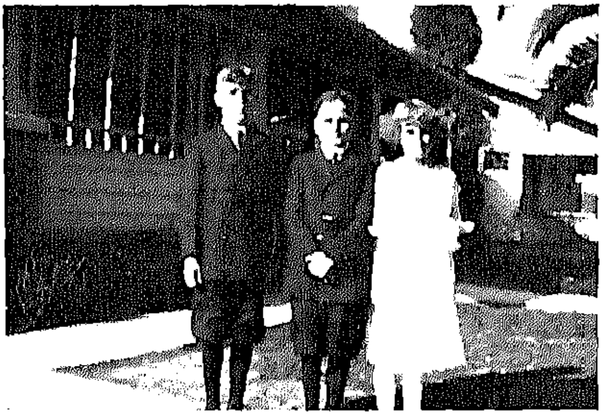


FIGURE 13

THE D TRIPLETS AT TEN YEARS OF AGE

TABLE 13

	Weight	Length
C.	6¼ pounds	19½ inches
W.	6 pounds	19 inches
Cn.	5 pounds	19 inches

When they were babies they all looked very much alike; all were "tow heads" until about 12 or 13 years of age. At present C. has wavy brown hair, W. has straight brown, and the girl has much lighter, straight brown hair. The eyes of all are blue-grey, but of different shades.

The girl was always interested in girls' toys and girls' activities while the boys were always interested in boys' toys and boys' activities. Each child always took his own blame; if a parent or teacher blamed the wrong child, the guilty child always came forward. When the children were small, the girl always "mothered" and corrected her brothers. She has never shown greater interest in one of her triplet brothers than in the other, nor has she shown greater attachment toward her triplet brothers than toward her sibling brothers.

Each triplet has his own hobbies. C. cares most for basketball, while W. cares more for baseball. The girl was always active in dramatics in the grades and in high school. The boys did not care for dramatics at all. The boys always chummed with different boys.

In the eighth grade, while taking part in several extra-curricular activities, the girl found it necessary to stop school for a semester. The boys then entered high school a semester in advance of their sister. In order to be able to graduate together, the boys took easy courses for a half year, thus extending their high school work to four and a half years.

The mother reports that C. is interested in business; he likes to do things right, is thorough, likes to work hard, and to get something out of it. W. is helping an older brother in electrical work at present. He cares more for clerical work. Ca. is staying at home and is studying music. She cares more for home activities.

In interviews the investigators found the triplets to be excellent entertainers; they were congenial, witty, and clever in repartee. However, there was nothing in their appearance, ways, manners, expressions, or voices that suggested similarity.

The present heights and weights of the D triplets are as shown in Table 14.

INTELLIGENCE RATINGS

Each of the D triplets took the Terman Group, Form B, Intelligence Test at the beginning and at the end of their high-school courses. The tests were administered by testers from the high school attended. IQ's are recorded in Table 15.

The D triplets were unwilling to take another intelligence test; the investigators did not urge them to do so.

TABLE 14

	Height	Weight
C.	5 feet 10 inches	143 pounds
W.	5 feet 9 inches	147 pounds
Ca.	5 feet 4 inches	116 pounds

TABLE 15

TERMAN IQ'S OF D TRIPLETS

	Date	IQ
C.	1-16-24	88
	1-12-28	98
W.	1-16-24	93
	1-12-28	104
Ca.	1-16-24	84
	1-12-28	83

SCHOOL RECORDS

The transcripts of the D triplets' school records for Grades 9, 10, 11, and 12 show that C. and W. took the same courses and in all but three courses made grades of 3 or 3+. In Business Law and Social Problems C. made grades of 2, while W. made grades of 3; in Auto Shop each made grades of 2, and each made grades of 1 in the four years of Physical Education. Except for a grade of 1 in Domestic Art, Ca. made grades of 2 or 2+ in all courses throughout the four years of high school. (Passing grade of school is 3; grade for college recommendation is 2.)

Ca. attended a large state university for about six weeks, then left in order to take a trip to Hawaii. She does not plan upon going back to school. The boys are not planning upon taking college courses.

V

HANDWRITING OF THE H AND OF THE LOS ANGELES TRIPLETS

A study of the handwritings of the H triplets and the Los Angeles triplets follows. This study was made by J. Clark Sellers, examiner and photographer of suspected and disputed documents. The very limited number of handwriting specialists of Mr. Sellers' standing makes this portion of the study a very valuable contribution.

FOREWORD

It appears that there is no other act a person performs which is so identifying as his handwriting.

Every writer forms certain habits in writing which are characteristic of that particular individual. No two persons look exactly alike, no two persons talk exactly alike, no two persons do any particular task exactly alike which calls for the coordination of a group of muscles. Because of the latter fact, no two persons write exactly alike. While the hand, arm, wrist, and fingers contain the same number of muscles, having the same general function in each person, it appears certain that in no two persons are these muscles developed alike in their capacity to coordinate, or in their ability to obey the will of the writer. If the writing factors are individual to each person, then the handwriting produced by those factors must be individual to each person.

The writing of another may be closely imitated, as far as general pictorial effect is concerned, but the muscular habit and personal writing impulse are extremely difficult, if not impossible, to imitate successfully either by design or by accident, and it is due to this fact that identification may be made from handwriting, when properly examined.

The microscope enables one to go into fields where the imitator does not go. Under the microscope the halting stroke, irregular line, and nervous tremor due to conscious effort and patchwork, which are so frequently found in a forgery, are clearly discernible.

The natural writing of an adult is normally free and automatic and is done without conscious effort, whereas the forgery is nearly always written in a slow, hesitating manner, producing a halting, irregular line resulting in an unnatural appearing writing. Due to the extreme care taken, the forger usually writes with a finger movement, as he cannot use ordinary free hand movement and closely imitate the writing of another. Therefore, to gain better control he uses a constrained finger and hand movement that necessitates frequent lifts of the pen, as the distance he can write in this manner is very limited. When the pen is lifted the forger usually retraces the preceding stroke for a short distance endeavoring to "blend in" the two strokes so the pen lifts will not be noticed. This condition is greatly different from the pen lifts due to habit.

Pressure, shading, and the manner of holding the pen are frequently highly individual and should be taken into consideration.

A simulated writing will almost invariably contain characteristics it should not contain, and characteristics it should contain are almost sure to be omitted.

Most people are not familiar with the identifying characteristics of their own writing. Very few are familiar with the identifying characteristics of the writing of another. And if one were familiar with all the characteristics of his own handwriting and familiar *with all the characteristics of the writing of another, even then he* could not produce the writing of the latter, because his mind could not control the muscles to such an extent as to omit all of his own handwriting characteristics and inject all the handwriting characteristics of the other.

THE H TRIPLETS AND THE LOS ANGELES TRIPLETS

Frequently a handwriting expert on the witness stand is asked the following question, "If two or more persons learned to write the same handwriting system, will not their writing so nearly resemble each other that it will be impossible to identify the writers by their handwriting?"

Of course, if they were all taught to write from a common model and each was able to reproduce exactly the form and writing movement of the model, then each one would write exactly alike. However, practical experience will demonstrate to anyone that students do not accurately reproduce the model forms placed before them in the penmanship class.

The manner and the degree to which each person diverges from the form taught constitutes the individual writing habit of that person.

The present cases of the H triplets and the Los Angeles triplets are most interesting and most valuable studies of the limitations as well as the strength of identification by handwriting.

The conditions under which the specimens of handwriting were obtained were as nearly the same as it was possible to arrange. The triplets in each case wrote exactly the same text from a common typewritten letter. Each of the triplets wrote the specimen with the same pen, with ink from the same bottle, and while seated at the same table. None of the triplets watched the others write, and each specimen was put out of sight as soon as it was written so that none could consciously or unconsciously attempt to copy the writing of any of the others.

The H triplets had gone to the same grade school and through the same high school together, had taken penmanship from the same teachers, and were taught the same system of penmanship, namely, the Palmer System.

The Los Angeles triplets had also learned to write the same System of writing, namely, the Zaner and Bloser System.

A study of each of the specimens of each set of triplets forcibly brings forward the caution that it is dangerous to attempt to make an identification from a limited amount of handwriting. Note the word "trip" in the second line of the H triplets' specimens. These words are so nearly alike that it would be dangerous to attempt to make a positive identification from that one word.

It appears just as evident that with a larger amount of handwriting each one of the triplets has developed certain individual idiosyncrasies in handwriting which make it quite evident each triplet can be distinguished by his handwriting.

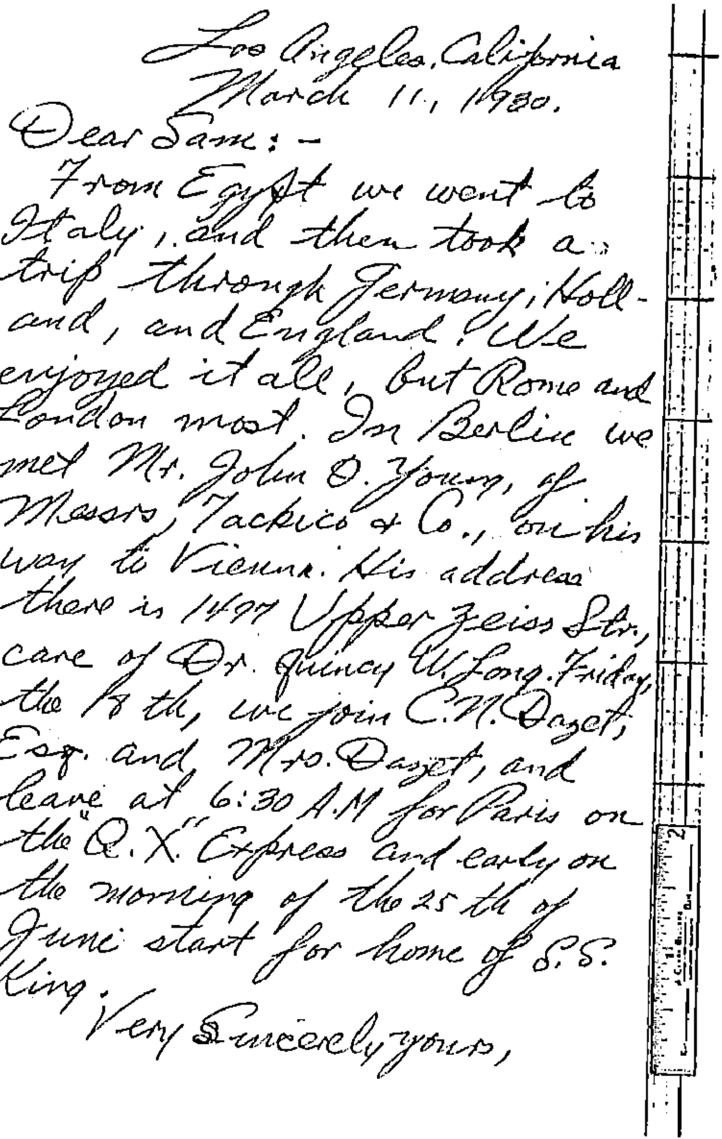
The question has been asked as to whether or not any two of each trio write more nearly alike. In the writing of the H triplets, the writing of W. and J. appear more similar and H.'s contains more divergencies.

The writing of the Los Angeles triplets shows less maturity and probably fewer writing peculiarities than found in the handwriting of the H triplets, nevertheless there are sufficient peculiarities and habits already developed in the handwriting of the Los Angeles triplets by which each one can be distinguished and identified. Pictorially, Ray.'s and R.'s writing resemble each other very closely, but a careful examination of each letter does not bear this out. In fact, R. appears to have developed more individuality in writing than either of the others.

It appears the handwriting of these two sets of triplets provides an answer in some measure at least to the oft-repeated question, "Can persons be distinguished or identified by their handwriting regardless of similarities in environment, writing systems learned, and hereditary influences on the muscular and nervous makeup of the writer?"

Respectfully submitted,

[Signed] J. Clark Sellers,
Examiner and Photographer of
Suspected and Disputed Documents.



Los Angeles, California
March 11, 1930.

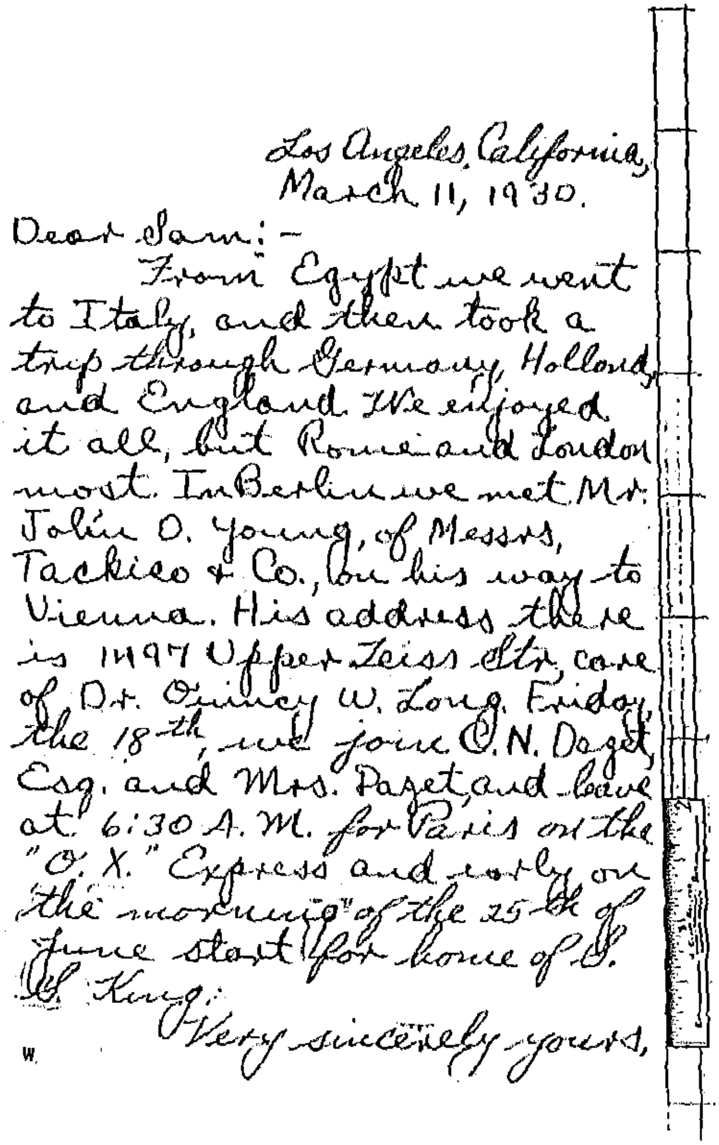
Dear Sam:-

From Egypt we went to Italy, and then took a trip through Germany, Holland, and England. We enjoyed it all, but Rome and London most. In Berlin we met Mr. John O. Young, of Messrs. Tackico & Co., on his way to Vienna. His address there is 1497 Upper Zeiss Str., care of Dr. Quincy W. Long. Friday the 18th, we join C.M. Dazet, Esq. and Mrs. Dazet, and leave at 6:30 A.M for Paris on the "Q.X." Express and early on the morning of the 25th of June start for home of S.S. King.

Very Sincerely yours,

H

FIGURE 14
Handwriting of H. (H Triplet)



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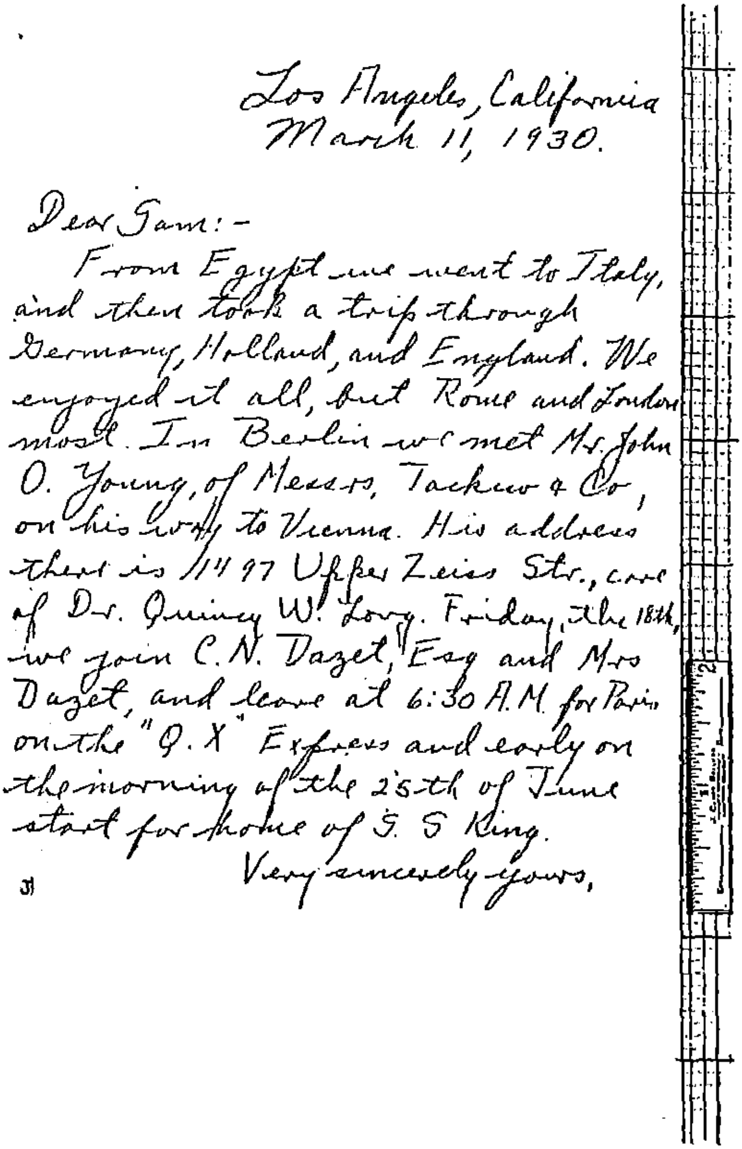
Very sincerely yours,

W.

FIGURE 15
HANDWRITING OF W. (II TRIPLET)



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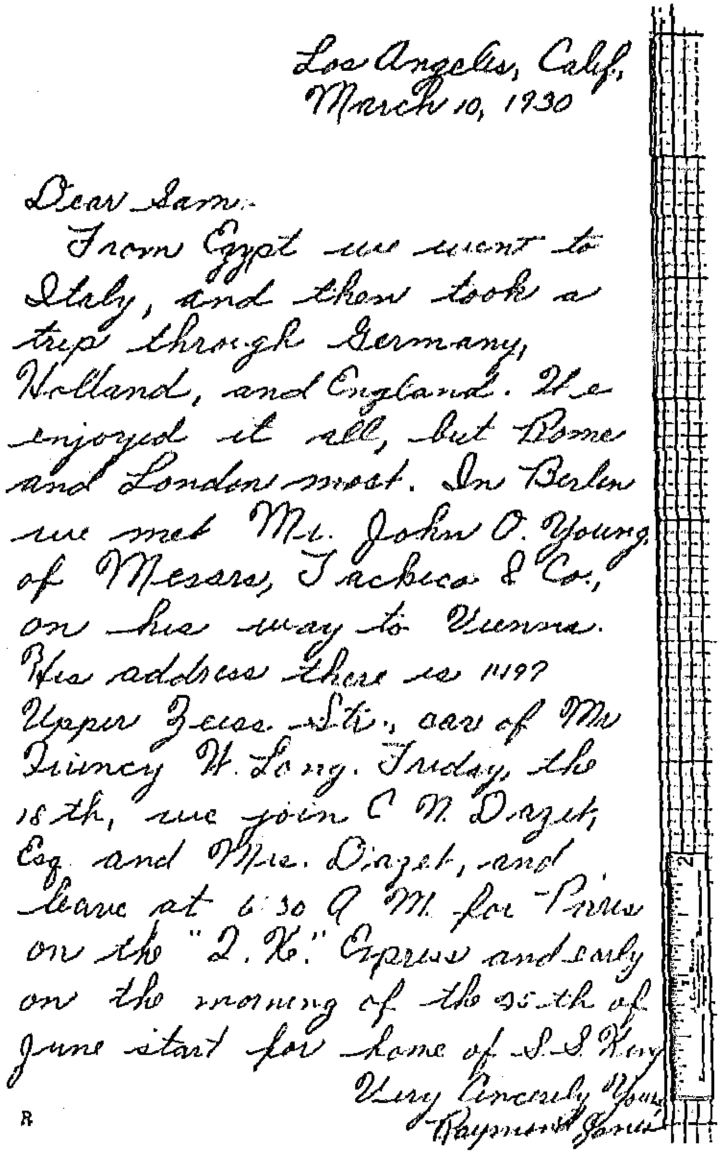
Very sincerely yours,

FIGURE 16
HANDWRITING OF J. (H TRIPLET)



Los Angeles, Calif,
March 10, 1930

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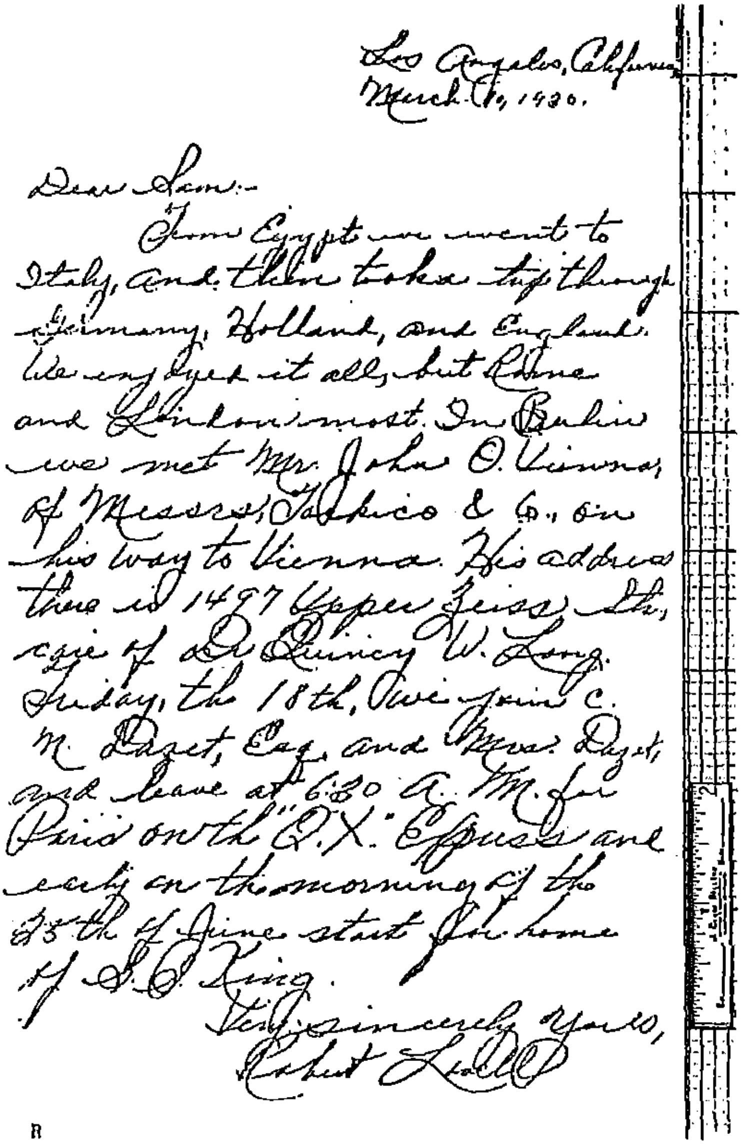
on his way to Vienna.
His address there is 1197
Upper Zeiss St., care of Mr
Quincy W. Long. Friday, the
18th, we join C N. Dozet,
Esq. and Mrs. Dozet, and
leave at 6:30 A M. for Paris
on the "Z. K." Express and early
on the morning of the 25th of
June start for home on S. S. Kay
Very Sincerely Yours
Raymond [illegible]

R

FIGURE 17
Handwriting of Ray. (Los Angeles Triplet)



Los Angeles, California
March 4, 1930.

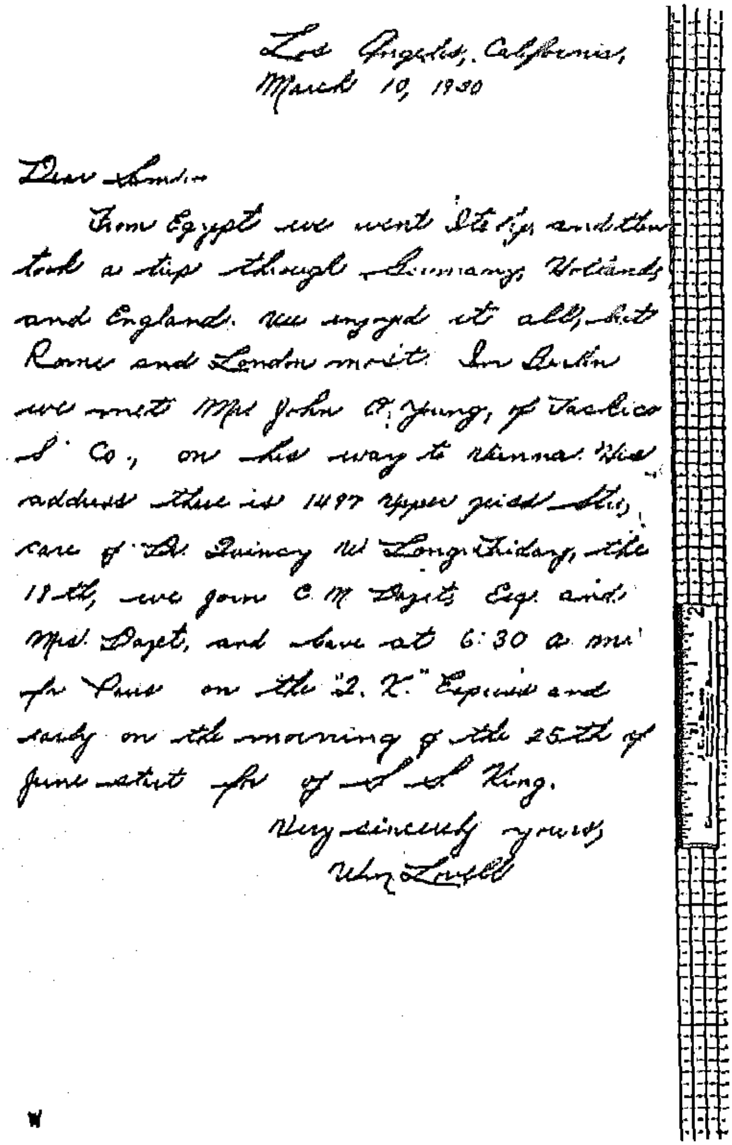
Dear Sam:-

From Egypt we went to Italy, and then took a trip through Germany, Holland, and England. We enjoyed it all, but Rome and London most. In Berlin we met Mr. John O. Vienna, of Messrs. Tapkico & Co., on his way to Vienna. His address there is 1497 Upper Zeiss St., care of Dr. Quincy W. Long. Friday, the 18th, we join C. M. Dazet, Esq. and Mrs. Dazet, and leave at 6:30 A. M. for Paris on the "Q.X." Express and early on the morning of the 25th of June start for home by S. S. King.

Very sincerely yours,
Robert Lidell

R

FIGURE 18
HANDWRITING OF R. (LOS ANGELES TRIPLET)



Los Angeles, California,
March 10, 1930

Dear Sandy —

From Egypt we went to Italy, and then took a trip through Germany, Holland and England. We enjoyed it all, but Rome and London most. In Berlin we met Mr. John O. Young, of Mexico & Co., on his way to Vienna. His address there is 1497 Upper Zeiss Str., care of Dr. Quincy W. Long. Friday, the 18th, we join C. M. Dazet, Esq. and Mrs. Dazet, and leave at 6:30 a.m. for Paris on the "Z. X." Express and early on the morning of the 25th of June start for [illegible] King.

Very sincerely yours,
Wm Lovell

W

FIGURE 19
HANDWRITING OF W. (LOS ANGELES TRIPLET)

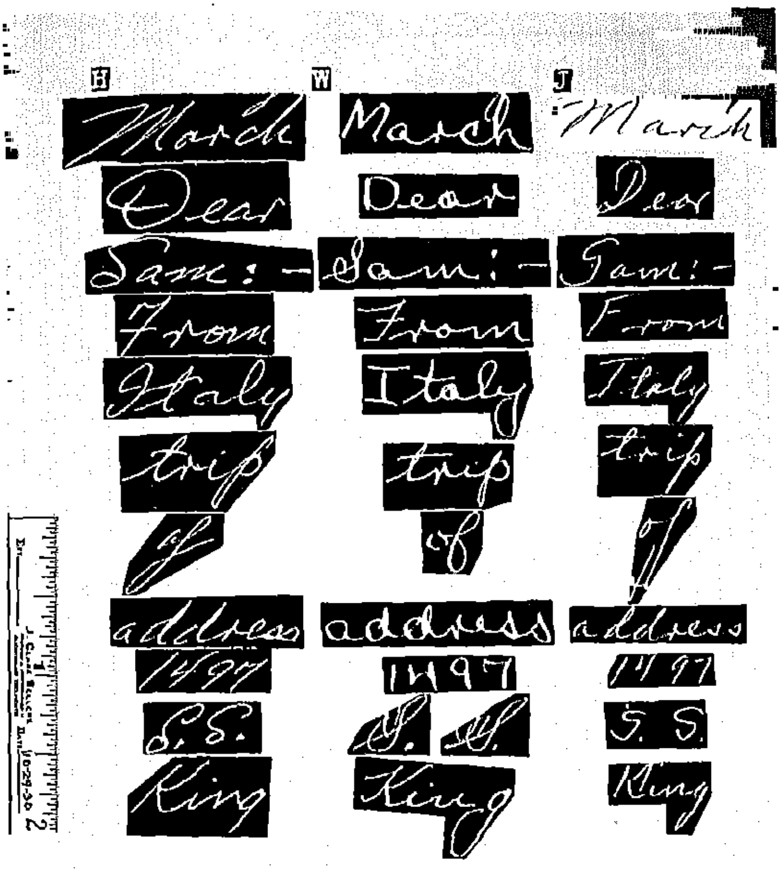

H
W
J
March
Dear
Sam: -
From
Italy
trip
of
address
1497
S. S.
King
March
Dear
Sam: -
From
Italy
trip
of
address
1497
S. S.
King
March
Dear
Sam: -
From
Italy
trip
of
address
1497
S. S.
King

FIGURE 20

A COMPARISON OF THE HANDWRITING OF THE H TRIPLETS

Selections taken from the same relative position in letter written by request by each of the triplets, H., W., and J. Each in turn copied the text of the letter from a common typewritten model, using the same pen and ink from the same bottle. None had access to handwriting of the other two from which he could consciously or unconsciously copy the forms used by the others. There is sufficient handwriting shown here to establish definitely these selections as having been written by three individuals, yet an interesting lateral comparison of similarity in some of the letter forms used by each in the same words can be made.

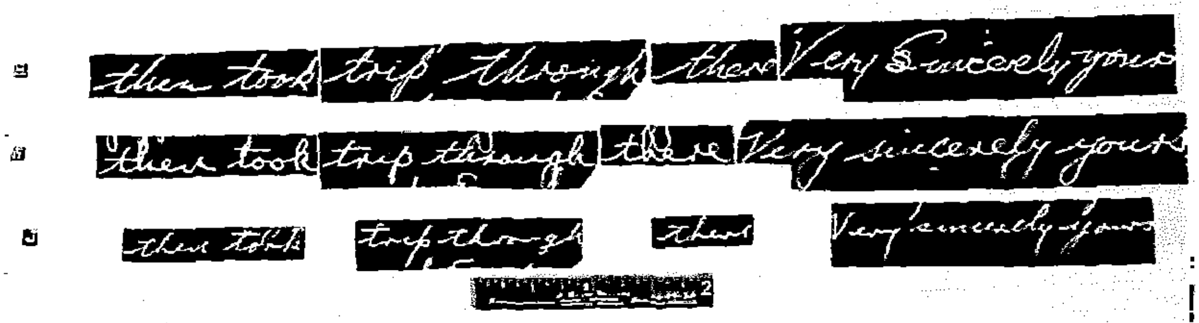

then took trip through there Very Sincerely yours
then took trip through there Very sincerely yours
then took trip through there Very sincerely yours

FIGURE 21

COMPARISON OF THE HANDWRITING OF THE H TRIPLETS

This arrangement of the handwriting of the H triplets demonstrates the danger of attempting to make a handwriting identification with too little writing from which to make a comparison. To attempt identification with *only* "Then took" or "trip through" available for study might be dangerous.

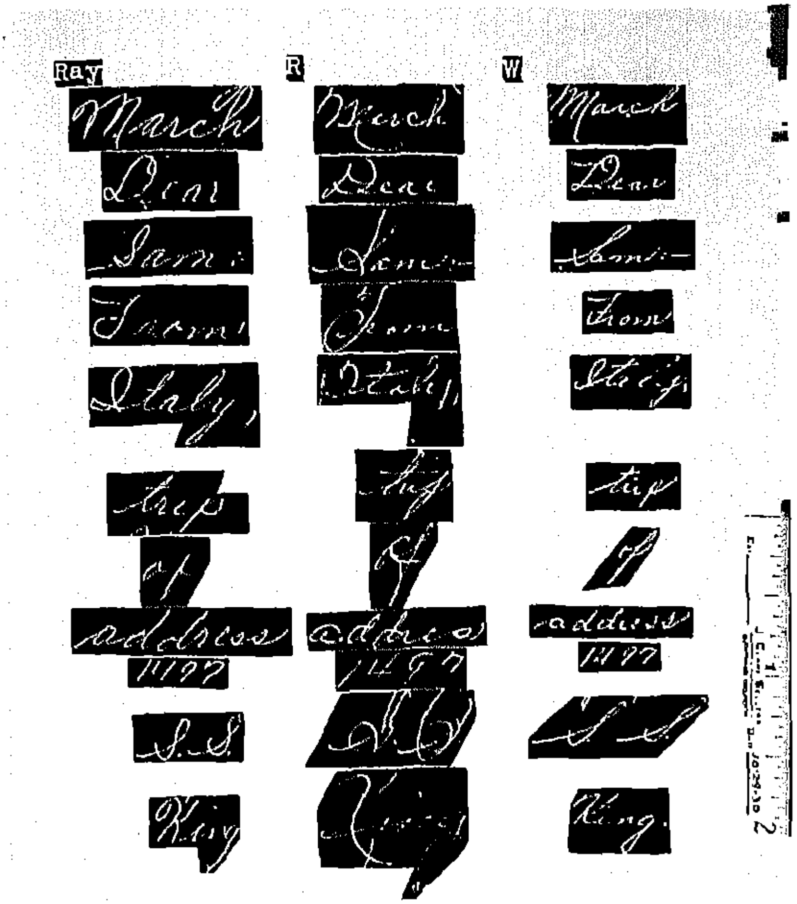


FIGURE 22

A COMPARISON OF THE HANDWRITING OF THE LOS ANGELES TRIPLETS

Selections from the handwriting of each of the triplets, Ray., R., and W., taken from a letter which each copied from a common typewritten model, using the same pen and ink from the same bottle. R. and W. are strikingly similar physically. A lateral comparison of the manner in which each writes the same word is interesting.

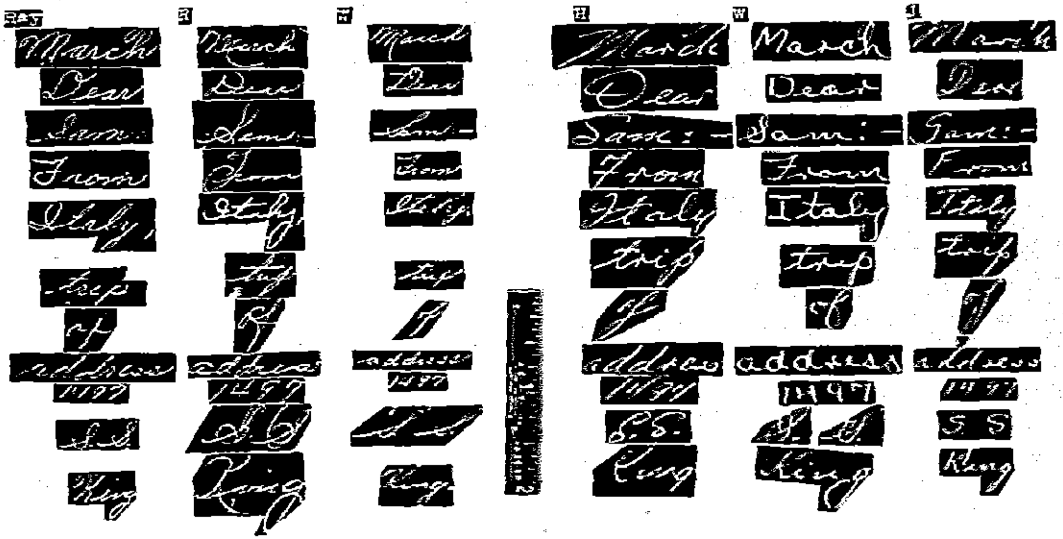


FIGURE 23

A Comparison of the Handwriting of Two Sets of Triplets

An interesting comparison of the handwriting of two sets of triplets, wherein the six individuals have written the same text under as nearly as possible the same handwriting conditions. Selections were made from the same relative word or numeral in each of the six writings. Note the group similarity in the pictorial effect of the writing, although a comparison of word for word and column for column shows clearly that the six handwritings are the product of six individuals.

VI

POSSIBLE GENETIC RELATIONSHIPS AMONG TRIPLETS

The literature on the phenomena of tripling is very limited, since tripling is in reality the process of twinning repeated either simultaneously or in rapid succession. Thus the findings of twins are considered to be doubled or duplicated in the case of triplets. The repetition of the twinning process, however, does more than double the possible genetic relationships among triplet offspring.

In the case of twins, two general types are commonly recognized, single ovum (monozygotic) and bi-ova (dizygotic). Monozygotic twins often are referred to as duplicate or identical, since they are found to be very much alike; their genesis is thought to be a single ovum fertilized by a single spermatozoön. Dizygotic twins, called siblings or fraternal, are not found to bear as close resemblance as the monozygotic. Usually the resemblance is closer than that of siblings of different ages since contemporaneous spermatozoa and ova are, perhaps, more alike than those developed at different times. Dizygotic twins are thought to originate from two ova fertilized by two spermatozoa.

Thorndike (29, p. 44), in measuring fifty pairs of unselected public-school twins, found the resemblance of twins to be approximately .80 in amount. When all these twin pairs were ranked according to the degree of resemblance, a curve (Figure 24) resulted that led Thorndike to question whether twins represent two dis-

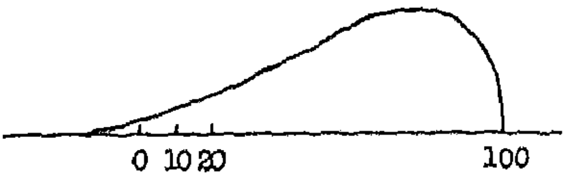


FIGURE 24
DISTRIBUTION OF RESEMBLANCE CURVE OF FIFTY PAIRS OF TWINS
From Thorndike (29)

tinct modes of fertilization and genesis. Instead of a bi-modal curve, the curve showed the closest likenesses to grade off gradually into notable differences. The most identical twins, moreover, were found in *some* respect to be less like each other than ordinary siblings.

Danforth (7), in regard to the extent of similarity in biovular twins, says:

> "It may be assumed that biovular twins will on the whole resemble each other to a degree about equal to the average for all children of the same family. In individual sets the degree of resemblance will vary widely, since the possible combination of traits from the maternal and paternal germ plasms are very many.[1] It is conceivable that occasionally (with our population and birth rate, perhaps once in eight or ten years) a pair of biovular twins would be born with identical germ plasms. More frequent should be biovular twins differing in only one chromosome, and progressively more frequent the pairs differing by larger and larger degrees until the average of fraternal resemblance is reached. Then progressively less frequent should be pairs differing to increasing degree below the fraternal average."

Biologists give us various modes of monozygotic twinning. Newman (19, p. 131) says that there are three, namely:

---

[1] "On the assumption that chromosomes maintain their individuality and that 'crossing over' does not occur, there would still be no less than 4,096 possible kinds of germ cells to be produced by a given individual of either sex" (Danforth's footnote).

1. Fission of the blastoderm,
2. Double gastrulation, and possibly
3. Complete fission of the bilateral halves of a single embryonic axis.

Williams (see 9, p. 425) recognizes four possible ways of producing single-ovum twins:

1. Fertilization of two polar bodies,
2. Premature separation of one or more blastomeres from a segmenting ovum,
3. Cleavage of the embryonic area, and
4. Double gastrulation of the blastodermic vesicle.

A retarding agency in the development of the fertilized egg is commonly considered conducive to the twinning phenomenon. Newman (19, pp. 133-134) cites three possible retarding agents as follows:

1. *Understimulation of the egg due to some defect in the development-initiating mechanism of the sperm.* Davenport found that twinning is rather strongly inherited in the male line. Newman adds that only one-egg twinning could be inherited through the male line, for twinning as a result of this factor could be possible only in the case of monozygotic twins, since dizygotic twinning is a phenomenon of ovulation and does not concern the male. An understimulated ovum would be retarded and would undergo belated fission; the degree of retardation would determine the consequences.

2. *Belated placentation due to failure of the corpus luteum to stimulate the uterine mucosa.* Newman explains that some "physiological discoördination between the various intricately interdependent factors responsible for implantation of the ovum" are involved in this condition. The objection that according to this view a given mother would always produce twins, since the same mechanism presumably would persist throughout the reproductive life, is met with the suggestion that possibly single offspring from parents exhibiting one-egg twinning are not true single offspring, but that each represents a survivor of a pair of twins, one of which succumbed to hazards present in connection with one-egg twinning. Newman considers this the least objectionable theory of twinning in man.

3. *An hereditary character dependent upon a recessive gene.* A gene acting as a growth-retarding factor, causing a temporary "period of quiescence," *may result in a belated placentation and twinning.* According to this theory, twinning could be transmitted as readily through the female as through the male line. Some of the zygotes, in the case of parents heterozygous for the twinning gene, would be monozygous for the character and twinning would result. In such matings, single offspring could occur also. Newman considers this genetic theory of twinning rather fantastic, but, in view of Davenport's findings, does not wish to exclude it as one of the possibilities.

In general, all theories as to the genesis of twins may be grouped into four categories, namely, those pertaining to

1. Ovulation and sperm maturation,
2. Fertilization,
3. Ovum fission, and
4. Chromosomal characters.

Newman's and Williams' theories presented above cover causes and modes of ovum fission. Davenport's findings have been cited to explain ovum segmentation as a result of chromosomal characteristics. Fertilization in these theories is taken to be the result of a single spermatozoön uniting with a single ovum (except Williams' theory of fertilization of two polar bodies which necessarily would require two spermatozoa).

A chromosomal theory, other than a growth-retarding gene, may account for additional twin and triplet genesis. During the series of cell divisions, the chromosomes of sex-cells divide longitudinally by the typical process of mitosis and retain their number throughout. It may be possible that this mitotic division is a double division (due to a recessive gene, stimulating mitotic division), not in one case out of 10,000 fertilizations (incidence of triplets), but in one case out of, perhaps, 330,000 cases (if all below cited types of triplet genesis occur about equally). Double and triple longitudinal division would result in two and in three sets of chromosomes so that two or three nuclear formations are possible in both the male and in the female cells. Gesell (9, p. 425) points out this possibility when he says that "we must recognize the indisputable occurrence occasionally of an ovum with double germinal vesicle (two nuclei). Boveri has suggested the additional possibility,—actually demonstrated on eggs of sea-urchins and bees—that a sperm may occasionally unite with only one half of a precociously divided ovum, leaving the other half to develop parthenogenetically (Danforth)."

It is possible for an ovum to be penetrated by *two* spermatozoa. Customarily this does not happen. That it does happen infrequently is pointed out by Holmes. "Eggs frequently exhibit a curious reaction which prevents them from being entered by more than one sperm," says Holmes (11, pp. 156-157). "The first sperm cell that succeeds in penetrating into the egg cytoplasm stimulates it to undergo a change at the surface, which prevents other sperms from gaining entrance. Were it not for this delicate and rapid reaction, eggs might be fertilized by several sperm cells. When this occurs, as it does under exceptional circumstances, it frequently leads to abnormalities of development." When the "exceptional circumstances" include a binuclear ovum, the simultaneous penetration of two spermatozoa may cause no abnormality of development other than two well-formed offspring—uni-ovum-bi-spermatozoa twins. Should but one spermatozoön penetrate a two- or three-nuclear ovum, only one nucleus could be developed. We must also recognize that possible triplet relationships may be multiplied according to the relationship of the fertilizing male cells. Cell division of the female sex-cell is very unequal so that only one large cell matures and three small polar bodies, formed by reduction division, soon disintegrate without taking part in development. In

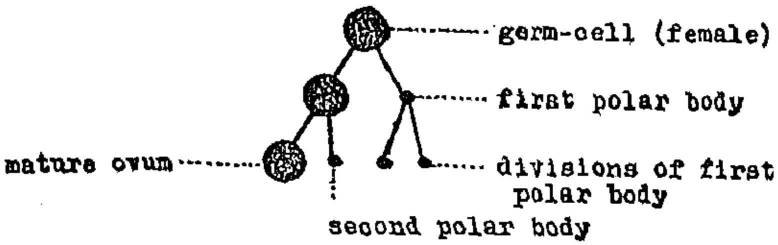


FIGURE 25

Diagram Showing the Genesis of the Ovum

After T. Boveri

A similar diagram in which all the daughter cells were of equal size would illustrate the genesis of four spermatozoa.

the case of the male cell, the cell division is equal and takes place twice so that *four* spermatozoa result from the maturation of a single male germ-cell (Figure 25). Since these four germ-cells are derived from the same single cell, they may be considered "identical." According to current views the four germ-cells are considered as being comprised of two sets of two identical cells, that is, only cells and their polar bodies are considered identical. The four mature cells, however, that are derived from a single cell are of identical structure and may well be considered identical. Moreover, these four cells may be in closer juxtaposition and may have equal characteristics of virility and attractability to the same or to several germ-cells of the opposite sex. Thus, multiple offspring may be paternally identical or paternally sibling according to whether they are fertilized by identical or by sibling spermatozoa respectively. Likewise, offspring may be maternally identical or maternally sibling according to whether they are developed from identical or from sibling ova respectively.

In order to analyze all possible relationships among triplets it may be expedient to list all possible types of spermatozoa and ova that may be the genesis of triplet offspring. Table 16 gives these respective types.

TABLE 16

TYPES OF GERM-CELLS THAT MAY BE POSSIBLE GENESIS OF TRIPLET OFFSPRING

Male	Female
1 Sperm	1 ovum
2 sib. sperms	2 sib. ova
2 iden. sperms	2 iden. ova
3 sib. sperms	3 sib. ova
3 iden. sperms	3 iden. ova
2 iden. sperms and 1 sib. sperm	2 iden. ova and 1 sib. ovum
1 3-nuclear sperm	1 3-nuclear ovum
1 2-nuclear sperm	1 2-nuclear ovum
1 2-nuclear sperm and 1 sib. sperm	1 2-nuclear ovum and 1 sib. ovum
1 2-nuclear sperm and 1 iden. sperm	1 2-nuclear ovum and 1 iden. ovum

Figure 26 presents the various possible modes of fertilization of each germ-cell. The particular occurrences of mitosis are not designated in this scheme, but are so obvious that the reader will readily understand where they take place. This figure shows that there are 33 possible modes of fertilization of germ-cell (or cells) giving rise to triplets. This does not discriminate between modes of monozygotic twinning enumerated above, nor does it include the theory of polar-body fertilization presented by Williams, nor does it show the two possible combinations in two cases.

It may be inferred that a late fission of the fertilized

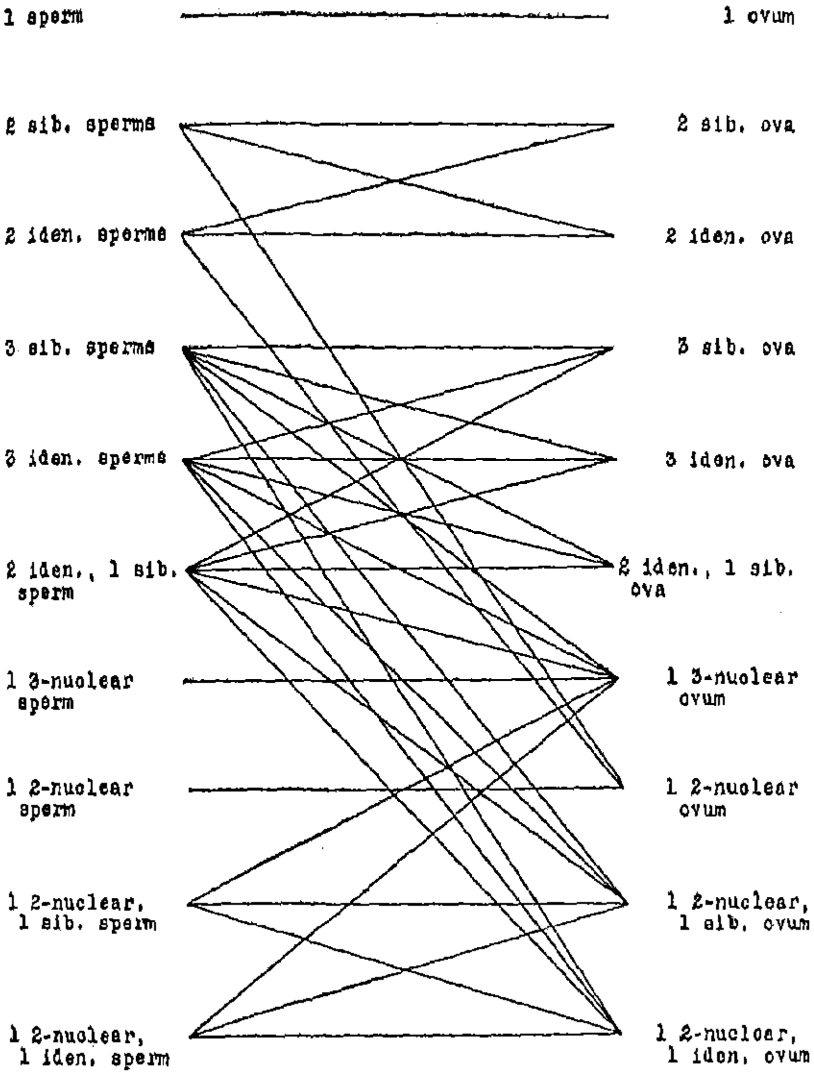


FIGURE 26

POSSIBLE FERTILIZATIONS OF GERM-CELLS GENERATING TRIPLET OFFSPRING

TABLE 17

POSSIBLE TRIPLET RELATIONSHIPS ACCORDING TO GERM-CELL GENESIS AND FERTILIZATION

Genesis	*Relationship*
I.	
1 ovum	
x 1 S, *then* ÷ 3	*Iden.*
x 1 S, one div. ÷ 2	Iden.
II.	
2 sib. ova	
x 2 sib. S, then 1 ÷ 2	2 iden.; 1 sib.
x 2 iden. S, then 1 ÷ 2	Pat. iden.; 2 mat. iden., 1 mat. sib.
III.	
2 iden. ova	
x 2 iden. S, 1 ÷ 2	Iden.
x 2 sib. S, 1 ÷ 2	Mat. iden.; 2 pat. iden., 1 pat. sib.
IV.	
3 sib. ova	
x 3 *sib.* S	*Sib.*
x 3 iden. S	Mat. sib.; pat. iden.
x 2 iden., 1 sib. S	Mat. sib.; 2 pat. iden., 1 pat. sib.
V.	
3 iden. ova	
x 3 iden. S	Iden.
x 3 sib. S	Mat. iden., pat. sib.
x 2 iden., 1 sib. S	Mat. iden., 2 pat. iden., 1 pat. sib.
VI.	
2 iden., 1 sib., ova	
x 2 iden., 1 sib. S	2 iden., 1 sib.
x 2 iden., 1 sib. S	2 mat. iden., pat. sim.; 1 mat. sib., pat. iden. with one and pat. sib., *mat. iden. with other*
x 3 sib. S	1 sib.; 2 mat. iden., pat. sib.
x 3 iden. S	2 iden.; 1 mat. sib., pat. iden.
VII.	
1 3-nuclear ovum	
x 1 3-nuclear S	Iden.
x 1 2-nuclear and 1 iden. S	Iden.
x 1 2-nuclear and 1 sib. S	2 iden.; 1 mat. iden., pat. sib.
x 2 iden., 1 sib. S	2 iden.; 1 mat. iden., pat. sib.
x 3 iden. S	Iden.
x 3 sib. S	Mat. iden., pat. sib.

TABLE 17 (*continued*)

Genesis	Relationship
VIII.	
1 2-nuclear ovum	
x 1 2-nuclear S, 1 + 2	Iden.
x 2 iden. S, 1 + 2	Iden.
x 2 sib. S, 1 + 2	2 iden.; 1 mat. iden., pat. sib.
IX.	
1 2-nuclear, 1 sib., ova	
x 1 2-nuclear, 1 sib. S	2 iden.; 1 sib.
x 1 2-nuclear, 1 iden. S	Pat. iden.; 2 mat. iden., 1 mat. sib.
x 3 sib. S	Pat. sib.; 2 mat. iden., 1 mat. sib.
x 3 iden. S	Pat. iden.; 2 mat. iden., 1 mat. sib.
x 2 iden., 1 sib. S	2 iden., 1 sib.
x 2 iden., 1 sib S (alternative)	2 mat. iden., pat. sib.; 1 mat. sib., pat. iden. with one and pat. sib., mat. iden. with other
X.	
1 2-nuclear, 1 iden., ova	
x 1 2-nuclear, 1 iden. S	Iden.
x 1 2-nuclear, 1 sib. S	Mat. iden.; 2 pat. iden., 1 pat. sib.
x 2 iden., 1 sib. S	2 iden.; 1 mat. iden., pat. sib.
x 2 iden., 1 sib. S (alternative)	2 mat. iden., pat. sib.; 1 mat. iden., pat. sib. with one and mat. sib. and pat. iden. with other
x 3 iden. S	Iden.
x 3 sib. S	Mat. iden.; pat. sib.

Abbreviations used: *S* = sperm and sperms; *x* = crossed with; *iden.* = identical; *sib.* = sibling; *mat.* = maternally; *pat.* = paternally.

ovum may result in greater similarity between the multiple offspring than an earlier fission. This cannot be presented expediently in schema, hence only pre- and post-fertilization devisions are taken into account. The fertilization of a polar body is not included since a pre-fertilization division of ovum offers all the possibilities of a mother cell and a polar body. A divided unfertilized ovum might, also, be more susceptible to fertilization and development than a polar body, since sufficient cytoplasm could be provided for each division in contrast to the limited amount of cytoplasm provided a polar body. However, if the reader wishes to include the possibilities of fertilized polar bodies he can keep in mind that the possibilities of fertilization and the relationships among triplets from this source are the same as those of the identical ova (unfertilized divided ovum). (Ordinarily the ovum and first polar body are not thought of as other than sibling, but since their structure is the same they may be considered as identical.)

The relationships among triplets can be interpreted readily from Figure 26. Table 17 specifies the relationships among triplets according to germ-cell genesis and fertilization.

In summary, we may say that there are, perhaps, 37 possible modes of triplet genesis giving rise to 10 distinct types of triplet relationships, namely:

1. Identical
2. Sibling
3. Two identical; 1 sibling
4. Paternally identical; 2 maternally identical, 1 maternally sibling
5. Paternally identical and maternally sibling
6. Maternally identical; 2 paternally identical, 1 paternally sibling
7. Maternally identical and paternally sibling
8. Two maternally identical and paternally sibling; 1 maternally sibling, paternally identical with one and paternally sibling, maternally identical with other
9. Two maternally identical and paternally sibling; 1 sibling

10. Maternally sibling; 2 paternally identical, 1 paternally sibling

The degrees of similarities and differences among triplet offspring may be influenced by the type of relationship and also by the mode of genesis.

VII

PLACENTAL RELATIONSHIPS

For the layman the number of placentae is usually considered the index of the relationship of triplets. However, paternal relationships cannot be inferred from the number of placentae nor can all types of maternal relationships be thus determined. Moreover, a most careful examination often is necessary in order to determine singularity or plurality of placentae.

The placenta consists of chorio-amnionic membranes, plus the decidua basalis of the maternal uterus. The amnion is a structure usually distinct for each individual twin or triplet unit, irrespective of identicality. This situation is due to the fact that the amnion is a development of the embryo *per se,* whereas the chorion is a wall of the original blastodermic vesicle, and where this is a unit structure, as it presumably is in identical siblings there will naturally be but one chorionic formation. A number of cases have been collected of apparently single amnions in identical twins (Holzapfel), but it is generally believed that this circumstance represents in reality a perforation of two originally separate amnionic membranes.

Placentae will, then, always be multiple in maternally fraternal embryos and single in the maternally identical type. It often happens, however, even in non-identical fetuses, that there exists an *apparently* single placenta. This is due to closely adjacent implantations on the uterine wall, with resultant fusion.

With anything less than intensive examination, then, these cases may be described as single-placenta instances and have undoubtedly caused some confusion. This circumstance is reported by the physician who attended at the delivery of the D triplets. One boy and the girl apparently were attached to a single placenta, a circumstance giving rise to confusion until it is viewed as a probable instance of implantation close together with subsequent fusion of two originally distinct placentae. It is quite possible, of course, to find relative retardation of one twin or triplet over the others, even in the case of identicals, due to some circulatory impairment in the area of the one placental segment, with preponderance of one anastomotic system over the other.

The single placenta reported by the physician in attendance at the delivery of the Los Angeles triplets could be explained in like manner. However, it is also possible that maternally these children are identical, but paternally perhaps only two are identical. The blond may be paternally sibling to his brunette triplet brothers. A single placenta would be possible in this case, and differences in hair and eye coloring would not preclude maternally sibling relationship.

Whether the physicians in attendance during the delivery of the triplets studied made intensive examinations of the respective placentae is not known. The physicians in two cases, for the Los Angeles and for the D triplets, preserved the placentae for about fifteen and twenty years respectively and used them for illustrative material when lecturing before medical classes, hence we may infer that their examinations were not superficial.

The measurements and findings of the triplets studied are presented, not with a view of substantiating any of our theories of relationships—the factors are too complicated and our instruments of measurement too crude for that—but rather to give the reader our data and to permit him to make his own speculations.

VIII

SUMMARY

The findings of three sets of triplets subjected to varying amounts of investigations have been presented. The three sets represent a progressive series of similarity. The first is, by all popular conceptions, an identical set; the second consists of two popularly considered identicals and an obvious odd; the individuals of the third set are clearly dissimilar.

The data of this study are the findings of standard physical tests and measurements, neurological examinations, psychological tests, personality and psychiatric investigations, as well as data on developmental history. Added to these are studies by specialists in the respective fields of finger-printing, handwriting, and dental formations.

It is believed that these data will be of value for certain definite reasons: first, as comparative material for subsequent check against similar studies; and, secondly, as a possible check against future developments in these individuals themselves. Pathological investigations of twins and triplets are of unusual interest and value; they would be of much more significance if made in comparison with previous intensive investigations of the same individuals when normal. Sooner or later physical or mental pathology is inevitable in the development of all individuals; it is then desirable to have at hand the findings long antedating this pathology.

It is believed that the findings of this study are within the limits of experimental error, and are of value in proportion to the value of the tests themselves. It seems possible that dissimilarities become manifest, in many fields, in proportion to the fineness of measurements available.

As a second part of the study, theories of 37 possible modes of triplet genesis, giving rise to 10 distinct types of relationship among triplets, are presented. This part of the study is frankly admitted to be speculative. It seems worth while to bring together these possibilities, hazarding what seem to the writers as legitimate opinions. This part, however, is a theoretical outgrowth of the objective work, and does not, of course, add or detract from the data themselves.

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UNE ÉTUDE DE TRIPLETS: AVEC DES THÉORIES DE LEURS RELATIONS GÉNÉTIQUES POSSIBLES

(Résumé)

Dans cette étude on a fait subir un grand programme d'investigation à trois groupes de triplets. Les trois groupes représentent une série progressive de similarité. Le premier est indentique, selon le jugement commun; le deuxième se compose de deux jumeaux identiques selon le jugement commun et un jumeau non identique; le troisième groupe se compose de trois jumeaux non identiques. Les résultats objectifs dans les domaines des mesures physiques, de la neurologie, de la psychiatrie, de la psychologie, et de l'éducation sont complétés par les résultats des spécialistes des domaines de la dentisterie, de l'écriture, et du système Bertillon de prendre des impressions des doigts.

Toutes les mesures physiques du premier groupe de triplets ont été similaires d'une façon surprenante. Des examens neurologiques ont montré un état apparemment identique des réflexes, des systèmes sensoriel et moteur; des examens ophthalmologiques ont montré un prolongement de la prunelle en chaque cas. Les résultats des tests mentaux ont été presque identiques; les transcriptions des notes scolaires montrent que presque les mêmes notes ont été reçues par ces triplets, quand même ils auraient suivi les cours avec des professeurs différents. Des conversations avec les professeurs, les employeurs, et les amis des triplets ont montré que nul trois individus ne pourraient peut-être se ressembler plus à l'égard de l'apparence, des intérêts, et de l'habileté que ces trois triplets. Les impressions des doigts cependant n'ont pas été indentiques et l'analyse de l'écriture par un spécialiste a montré des différences individuelles bien que l'écriture ait semblé identique à une personne non spécialiste. Des questionnaires pour tester la personnalité ont montré une similarité surprenante de réponses; sur 130 réponses pour chaque triplet toutes les réponses sauf onze ont eu complètement le même caractère. Où les variations se sont montrées, il n'a semblé être nulle relation constance entre deux des trois à l'égard du troisième.

Le deuxième groupe de triplets s'est composé de deux bruns et d'un blond. Les mesures physiques des bruns se sont beaucoup ressemblées et ont différé de celles du blond. Les résultats des tests mentaux et les notes scolaires ont indiqué que la différence entre les bruns n'est pas si grande que celle entre l'un ou l'autre des deux et le blond. Cependant les tests de vocabulaire, les tests d'habileté mécanique, les études de la personnalité, et les examens psychiatriques n'ont pas montré que les bruns se ressemblent l'un à l'autre plus que l'un ou l'autre ressemble au blond.

Les membres du troisième groupe de triplets ont eu des intérêts individuels. Nul jumeau n'a aimé plus l'un ou l'autre des autres deux jumeaux qu'un autre frère ou soeur, et les triplets ne se sont plus fréquentés qu'un autre frère ou soeur.

Outre les données de la recherche, les auteurs présentent trente-sept moyens d'origine des triplets lesquels causent dix relations distinctes entre les triplets. Ce grand nombre d'origine de triplets et de relations génétiques est basé sur la conception que les spermatazoïdes qui causent les triplets peuvent être identiques ou de parenté, et que les oeufs qui causent les triplets peuvent être identiques ou de parenté. Le croisement de divers types de spermatozoïdes et d'oeufs donnerait donc des enfants dont les relations dépendent de leur état identique ou de parenté paternal ou maternel.

Anderson et Scheidemann

EINE UNTERSUCHUNG AN DRILLINGEN, EINSCHLIESSLICH THEORIEN ÜBER IHRE MÖGLICHEN GENETISCHEN BEZIEHUNGEN

(Referat)

In dieser Untersuchung sind drei Drillingsgruppen einem ausgedehnten Forschungsprogramm unterworfen worden. Die drei Gruppen stellen eine in Bezug auf Änlichkeit abnehmende Serie dar. Die erste ist, der allgemeinen Meinung nach, eine identische Gruppe; die zweite besteht aus zwei allgemein als identisch angesehenen Mitgliedern und einem unverkennbar ungleichen; die dritte besteht aus drei ungleichen. Es werden objektive Befunde im Bereich der körperlichen Messungen, der Neurologie, der Psychiatrie, der Psychologie, und der Erziehung, durch Befunde von Spezialisten im Bereich der Zahnheilkunst, der Graphologie, und des Bertillonschen Fingerabdrucksystems ergänzt.

Alle körperlichen Messungen an der ersten Drillingsgruppe erwiesen sich als überraschend ähnlich. Die neurologischen Untersuchungen offenbarten einen anscheinend identischen Zustand der Reflexe, der Sinnesorgane und des Bewegungssystems [motor system]. Bei den Augenuntersuchungen wurden in jedem Fall Verlängerung des Augapfels ermittelt. Die an Intelligenzprüfungen erzielten Zahlen waren fast identisch. Notierungen der Schulzensuren weisen darauf hin, dass diese Drillinge fast die gleichen Noten erhielten, selbst wenn die Schulfächer unter verschiedenen Lehrern studiert worden waren. Gespräche mit Lehrern, Chefs, und Freunden der Drillinge haben erwiesen, dass drei Individuen wohl kaum möglich einander in Bezug auf Aussehen, Interessen, und Fähigkeiten, ähnlicher sein könnten, als diese drei Drillinge. Die Fingerabdrücke, aber, erwiesen nicht Identität, und eine sachverständige Analyse der Handschriften wies auf individuelle Unterschiede hin, obwohl die Handschriften einem Laien als identisch erschienen. Fragenbogen über die Persönlichkeit [personality test questionnaires] lieferten eine erstaunende Änlichkeit der Reaktionen. Die Art der Antwort war bei allen, mit Ausnahme von 11, der von jedem der Drillinge gegebenen 110 Antworten in den drei Fällen völlig gleich. Wo Abweichungen bestanden, schien keine beständige Beziehung zwischen zwei besonderen Mitgliedern der Drillingsgruppe im Gegensatz zu dem dritten Mitglied zu bestehen.

Die zweite Drillingsgruppe bestand aus zwei brunetten Mitgliedern und einem blonden Mitglied. Die Brunetten waren in Bezug auf ihre körperlichen Messungen einander sehr ähnlich, und unterschieden sich von dem Blonden. Die an Intelligensprüfungen erhaltenen Zahlen und die notierten Schulzensuren wiesen darauf hin, dass der Unterschied zwischen den Brunetten nicht so gross war, wie der Unterschied zwischen irgend einem der brunetten Mitglieder und dem blonden Mitglied. In Wörterschatzprüfungen, Prüfungen der Fähigkeit zu mechanischen Tätigkeiten, Persönlichkeits Untersuchungen, and psychiatrischen Untersuchungen, aber, zeigte es sich nicht, dass die Brunetten einander ähnlicher waren, als irgend einer von ihnen dem Blonden ähnlich war.

Die Mitglieder der dritten Gruppe erwiesen individuelle Interessen. Keiner von ihnen war irgend einem der anderen zwei stärker zugetan, als irgend einem anderen Kind-der-selben-Eltern (sibling). Auch waren die drei Drillinge nicht öfter beisammen, als sie mit dem anderen Kind-der-selben-Eltern (sibling) zusammen waren.

Die Verfasser liefern nicht nur Befunde aus Untersuchungen, sondern auch 37 Ursprungsweisen der Drillinge [modes of triplet origins], welchen zehn besondere Beziehungen unter Drillingen entspringen. Diese grosse Anzahl der Ursprünge und der genetischen Verhältnisse bei Drillingen stützt sich auf den Begriff, dass die zu Drillingen führenden Spermatozoen identisch oder geschwisterisch [sibling] sein können, und dass die zu Drillingen führenden Eier ebenfalls entweder identisch oder geschwisterisch sein können. Die Kreuzung verschiedener Spermatozoenarten und Eiarten würde also zu Nachkömmlingen führen, deren Beziehungen auf die Identität oder Geschwisterschaft auf väterlicher und mütterlicher Seite ankommen.

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Child Behavior, Animal Behavior, and Comparative Psychology

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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

THE OBJECTIVE MEASUREMENT OF EMOTIONAL REACTIONS*

From the Psychological Laboratory of The Ohio State University

By

HAROLD V. GASKILL

---

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I

THE PROBLEM AND ITS HISTORICAL ANTECEDENTS

There is a type of behavior or a category of reaction which the layman and the scientist alike call "emotion." The latter classification is the more rigorous and more exact, but both designations are primarily descriptive of the same behavior. The layman is concerned with his own fears, hopes, joys, and sorrows, or with those of his friends or enemies. The scientist is interested in the classification of these states, in their external manifestation, and in their more subtle bodily concomitants and expressions. Whether we are concerned with arousing a pleasant emotion in a prospect, quieting the excitement of a neurotic patient, detecting the guilt or innocence of a suspect, or merely with enlarging the range of knowledge regarding human behavior, the problem of emotion looms large. Past experiments and observations have extended along several lines—the subjective observation of the emotional state as such, the rough observation of grosser bodily reactions such as running or turning pale, performance of the individual in "pencil-and-paper" tests, and the more accurate recording of subtler physiological changes. The trend has been more and more toward the last of these approaches. It is rather generally conceded now that this is the most promising program.

However, while numerous studies of this sort have been made, they have usually included the simultaneous application of only one or two techniques. We find plenty of experiments on breathing or pulse rate or blood pressure or vascular distribution but made under different types of stimulating conditions. It is impossible, for example, to make accurate comparison of changes in breathing where one kind of stimulus was used with changes in pulse rate obtained under different stimulating conditions. What is needed is a more comprehensive study in which a considerable number of these physiological variables are recorded simultaneously while standard stimuli are applied. We may then note simultaneous trends in breathing, blood pressure, etc. The present study aims to do just this. We have employed a standard set of stimuli and stimulus situations on a large number of individuals in different experimental periods, with continuous records of a considerable number of bodily changes.

Interest in the expression of emotional reaction has been manifest by an enormously large number of individuals. As above suggested, we find all through the history of science a keen interest in the problem of the emotion—in fact, classifications have existed from the earliest times (10, 11).

The emotional life, as described by Plato and Aristotle, is dependent upon the manifestation of the primary drives—food, drink, and sex. The Stoics and Epicureans viewed emotion actually as forms of *motion* and gave directional components for this motion in two categories—positive and negative. Oriental writers describe emotions as somatic conditions.

Alexandrian physicians noted variations of pulse rate as indications of emotional reactions or changes in emotion. Descartes, influenced by physiological concepts, treated emotion or "passions" as mechanical events (50). An analysis of behavior into elemental emotional experiences has likewise been attempted by Hobbes, Cabanis, Gall, Lotze, James, McDougall, Watson, and many others. Lotze gave the first detailed statement of bodily changes in emotion, showing variation in facial expression, posture, respiration, and heart rate. Malebranche emphasized changes in heart rate and intensity of the contractions and dilations during emotion.

The novelists and dramatists were very early interested in the expression of emotion, especially in regard to facial expression and gestures. There are found in the history of the French stage quite complete and highly complicated directions for changes in facial expression to depict emotion (1). The biologists showed interest in the expression of emotion, but the most complete work, from the natural history standpoint, that of Darwin, did not appear until 1872 (23). Sir Charles Bell's work (4) has been called the first attempt to make a science of expression.

After the contribution of Bain and Lotze, there was a considerable amount of work done in the "expressive methods," especially in the latter half of the nineteenth century. The earliest investigations employing these methods in a more exact way were those of Külpe and Wundt. Using "physiological registration," Wundt greatly amplified the experimental quantitative methods.

A number of studies of physiological aspects of emotion led up to the work of Lehmann (47). The psychological importance of organic changes was pointed out by Lange (42), especially changes in dilation of the blood vessels with fright. His work was amplified by that of Mosso and Féré. Mosso showed fluctuation in the volume of blood in one of the larger limbs in emotional situations, and Féré showed increase in muscle capacity with each "pleasant sensation" as well as a correlative increase in the volume of blood in the limbs. Féré also demonstrated, as did Tarchanoff independently, that emotional disturbances were accompanied by a change of the difference in electrical potential between one point on the skin and another, causing a current which could be detected by a galvanometer. Also, during emotional state there was shown to be a decrease in bodily resistance to the transmission of an electrical current from an outside source. Lehmann reported changes in the volume of blood in the hand, in pulse rate, in the strength of the pulse, and in the rate and depth of breathing in emotional states.

The material published after Lehmann's work and prior to 1918 was rather voluminous. Among the contributions is the study of Forbes and Wells (29), in which a close relation between the psychogalvanic reflex and the intensity of the emotion reported by the subject was shown. Correlation techniques were not used, but the study was made quantitative by defining four levels of emotionality and by showing a correspondence of these levels to degrees of electrical disturbance recorded. Jung had previously used the psychogalvanic reflex in conjunction with the association test. Peterson (51) discussed the galvanometer as a "measurer of emotions."

The suggestions of Ferri and Lombroso about variations in blood pressure in detecting deception were carried out experimentally by Marston (49) in 1915, working at Harvard under Münsterberg. Marston reported that "fluctuations in the emotions of the witness being cross-examined were minutely and accurately indicated by fluctuations in blood-pressure." Cannon's work (17) in the same year established the fact of an increase of blood pressure in most fear and rage responses. Crile (18) discussed bodily changes in emotion, but carried out little experimental work.

In contrast to the conventional experiments concerned with rate and depth of breathing, Benussi (7) investigated the ratio between inspiration and expiration time with special reference to detecting the emotion present during false reports. He found the I/E (inspiration-expiration) ratio approaching unity after a false response and preceding a true response. Feleky (27) conducted experiments to show the influence of emotion upon respiration. These two studies were preceded by the work of Foster and Gamble (30), which was concerned with the effect of music on thoracic breathing. Accurate records of breathing as they are now obtained were not, however, used in this latter study.

Certain other physiological changes were measured in connection with studies of emotion in the period being discussed. Cannon's (17) work on endocrinology led to the measurement of body fluids as indicative of emotional reaction. It was found that "emotional tension" produced an increase in blood sugar. Cannon and Mendenhall (18) found also that in pain and emotional excitement the coagulability of the blood is increased. Many investigations were concerned with the excretion of nitrogen during excitement, during pain, or in extreme nervousness. Among the earlier of these studies was that of Benedict (5).

The effect of emotional stimuli upon the alimentary system also received attention. In some experimental studies Cannon (16) showed that some emotional states influenced the function of the alimentary canal, some emotional states aiding digestion, and others hindering digestion. Pavlov's work on the digestive glands is well known. Apparently there was no work in this period on the hydrogen ion concentration of saliva in varying emotional situations.

With the entrance of the United States into the World War, a large amount of work was done in measuring emotional reactions. Much of this was attempted with reference to selecting aviators. Henmon (32) discusses some of these techniques as tests of aptitude for flying. Marston (cf. 61), collaborating with Burtt and Troland, made a study of breathing and blood pressure, along with other measures, as symptoms of deception, with a view to military use.

Much of this work led to the devising of new apparatus and new techniques for measuring physiological changes (65). Many of the cardiac and respiratory changes were measured during changes in oxygen tension, during exposures to low oxygen, etc. (48; cf. also 56-58). Blood counts were also taken during these conditions. Dockeray and Isaacs (25) discussed the psychological research in aviation in Italy, France, England, and in the A. E. F. Emotional reactions in most instances were studied by recording changes in circulation, respiration, and tremor of the hand, and changes in blood pressure—systolic, diastolic, and pulse pressure.

From the close of the War to the present time, there has been wide interest in the measurement of emotional reactions. Many persons engaged in research during the War continued that research, and many others, stimulated by the results obtained in the military investigations, became interested. There seems to have been renewed interest manifested in "expressive method," much of which was due to the military research, and much probably due to the interest Münsterberg and others developed by suggesting that the physiological measures be applied to testing the veracity of witnesses. Dean Wigmore's attack, based upon the recency of discovery of the techniques suggested, seems also to have stimulated interest, both on the part of the legal profession and the psychologists.

Investigations involving the psychogalvanic reflex or galvanic skin reflex are not directly germane to our problem, so they will not be discusssed in detail. Many recent investigators have used these measurements in studying emotions. Cattell (19) has a résumé of the work done on the psychogalvanic reflex. An inclusive review of the electrical phenomena of the skin is presented by Landis and DeWick (39).

Among the experimental studies of blood pressure or of blood pressure and respiration, the first and most complete is that of Burtt (14).[1] The average I/E for the three to five breaths following the subject's answer was subtracted from the average I/E for the three to five breaths between the experimenter's question and the subject's reply. Systolic blood-pressure readings were taken at intervals. The diagnostic value of blood pressure in detecting deception was found to be superior to that of breathing. In one series, systolic blood pressure indicated correctly the guilt in 91% of the cases as compared with 73% for the breathing. Larson (43) used continuous records of respiration and blood pressure. In some earlier work he included reaction-time, but found in later work that irregularities in breathing and variation in blood pressure[2] were the most reliable measures. Larson's main contribution was the development of a graphic technique showing continuous records of respiration and blood pressure. He also carried the experiments formerly involving artificial guilt to actual situations in which the suspect had been charged with murder, burglary, or larceny, and to hundreds of cases of juvenile delinquency. He was able to verify, by confessions, the correctness of findings based on conclusions derived from breathing and blood-pressure records of 528 out of 861 juvenile delinquents tested (44-46).

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[1] For technique of obtaining I/E ratios cf. Burtt (13, 15).

[2] A combination measure of systolic and diastolic blood pressure is used with a technique similar to ours (*infra*).

Landis and Gullette (40), using Burtt's technique, found that certain emotional reactions could be measured in terms of breathing and blood-pressure changes, but it was impossible to distinguish characteristic blood-pressure symptoms for different emotions. Surprise is an exception, there being concomitant with this a sharp rise immediately followed by a fall. The different emotions, however, were classified by introspective report. Landis and Wiley (41), again using Burtt's technique and applying it to the testing of deception, did not confirm the earlier work of Burtt. They found breathing, e.g., I/E ratio, slightly superior to blood pressure in determining false reports, but in only slightly more than 60% of the cases.

Skaggs (62), presenting an electric shock, reports a characteristic inspiratory movement, after which breathing is accelerated and the heart rate is lowered. He also found the variations of breathing and pulse rate in the anticipation of the shock practically the same as those of experiencing the shock.

Blatz (8), studying the sudden shock produced by tipping the subject's chair over backward, found that an immediate acceleration followed by a marked retardation in heart rate occurred, then a prolonged acceleration followed by a gradual retardation. He found that there was a sudden inspiration following the stimulus, and a consequent retardation of respiration rate. Anticipation of the stimulus caused the same pulse effect as in actual occurrence.

Landis (37), using as variables blood pressure, metabolic rate, thoracic and abdominal breathing, and rectal and gastric contractions, made a study of a severe emotional reaction. No clear-cut and general results were obtained. For instance, the stimulus caused stomach contractions in one subject and checked them in another. This experiment was most carefully conducted and involved elaborate controls.

The more recent studies involving blood pressure, breathing, and pulse rate are those of Klemm (34), using Benussi's I/E ratio in testing prisoners on trial. Klemm's records do not contradict Benussi's, but appear in many instances as very ambiguous. Chappell (20), using blood pressure, was able to differentiate truth and falsehood with 87% accuracy. Blood-pressure changes in other experimental situations led to the conclusions that a rise in deception is due to excitement and that there is no characteristic curve for blood pressure in deception. Grollman (31) reported that in cases of mild disturbance, such as resentment, the cardiac output showed an increment of one-tenth liter, and in cases of extreme disturbance (anger) the increment was nine-tenths liter. Similar increments were observed in pulse and blood pressure, but oxygen consumption showed only a slight increase.

Basal metabolism, blood counts, gastro-intestinal activity, hydrogen ion concentration in saliva, vibrato in speech, reactions of facial muscles, and other measures have been used as variables in studies of emotion. X-ray and fluoroscopic studies of heart action have also been suggested. Landis (36) found a quick rise in metabolic rate during anticipation of severe pain and a very rapid fall during the pain, but the results are not well defined. Ziegler and Levine (66) have shown that emotional reactions affect basal metabolism. Segal (59) and his co-workers have observed the possibility of a "dangerous emotional metabolism rise" in the case of patients with toxic goiter who were not treated with iodine.[3] In a later study Segal (61) found no constant relation between basal metabolic rate, blood pressure, and pulse rate in individuals who were thinking of an impending operation. Totten (64) found no evidence of change in amount of oxygen consumed in situations in which a variety of emotional stimuli were used.

Dumas (24) has a comprehensive discussion of the vascular, glandular, and muscular reactions to emotional situations of a powerful and sudden nature. Analyses of blood have been made in similar studies. Using cats as subjects, Izquierdo and Cannon (33) have observed a marked increase in the red-corpuscle count during emotional excitement. Britton (12), also working with cats, showed that in excitement the blood-sugar level is increased. Bowman and Kasanin (9) point out that there is contradictory evidence regarding the effect of emotional states on the sugar content of the blood. They compare data from psychotic patients with data from persons clinically normal to show essentially the same distribution curves of sugar content, which is also contradictory. Benharnou and others (6) show definitely that there is abrupt splenic contraction in a normal individual under the influence of emotion. Co-variant with this is an immediate polyglobism, which seems to be closely related to the contraction of the spleen. One might infer a change in sugar content of the blood, since the spleen is most sensitive to adrenalin. Further unpublished work has been done on blood analysis by G. J. Rich, especially measurements of alkali reserve.

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[3] Bibliography on respiratory quotient and metabolic rate is found in an article by Richardson (54).

Measurements of the hydrogen ion concentration of saliva were obtained by Starr (63). A co-variation of pH and emotional excitability was shown. Rich (53) reports a definite though low negative correlation between emotional excitability and bodily acidity. Results obtained in the use of a ketogenic diet with epileptics were taken as further substantiation. The tests showed a positive correlation between the pH of saliva and the emotion—excitability of the individual. Saunders (55) had previously shown that fluctuations in the pH of saliva in epileptic patients are much greater than fluctuations in the salivary pH in normal persons.

Comprehensive discussions of the contemporary experimental work concerning the expression of emotions are found in the second edition of Cannon's (17) book, and in an article by Landis (38).

Of all of the physiological measures which have been used in the past—heart rate, blood volume, blood pressure, pulse pressure, blood analysis, including determinations of blood sugar, creatin and creatinin, alkali reserve, red- and white-corpuscle counts; urine analysis for nitrogen, bladder movements; measurements of respiration, including rate, volume, I/E ratios, and amounts of inspired oxygen, expired carbon dioxide, and basal metabolism; the galvanic skin reflex and bodily resistance; arm, leg, and head movements, postural changes, nystagmus; determinations of the hydrogen ion concentration of saliva, and measurements of stomach contractions—we have selected those for use in this investigation which have seemed to be most promising, judging from past results. We should like to have included blood analysis, but the mechanical difficulties presented by the large number of subjects together with a feeling of hesitancy about taking one cubic centimeter of blood from an individual ten or twelve times prevented this. Our preliminary studies and the results obtained in previous investigations by others led to the selection of the following for variables in this study:

1. Continuous breathing records from which rate, amplitude, and I/E ratios may be obtained,
2. Continuous records of blood-pressure changes, which may be read in terms of rises and drops, and heart rate,
3. Continuous records of movements of the right arm, and,
4. Measurements of the hydrogen ion concentration of saliva samples taken at intervals.

II

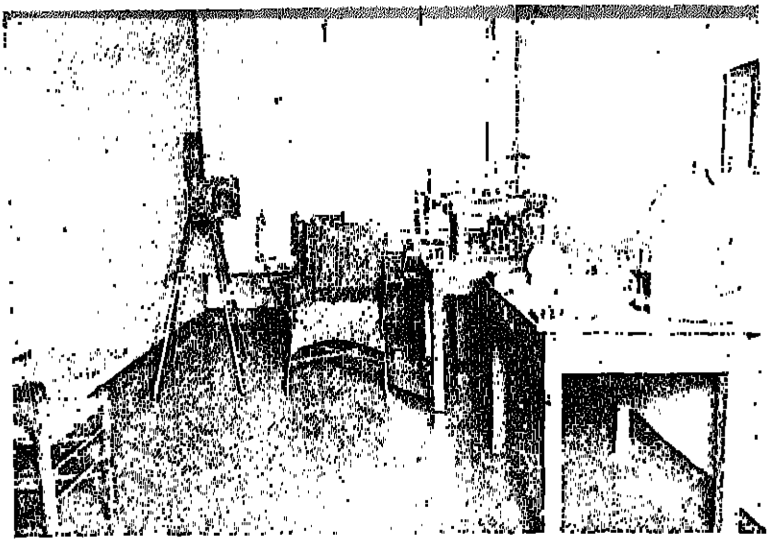
APPARATUS AND METHOD

A. RECORDING

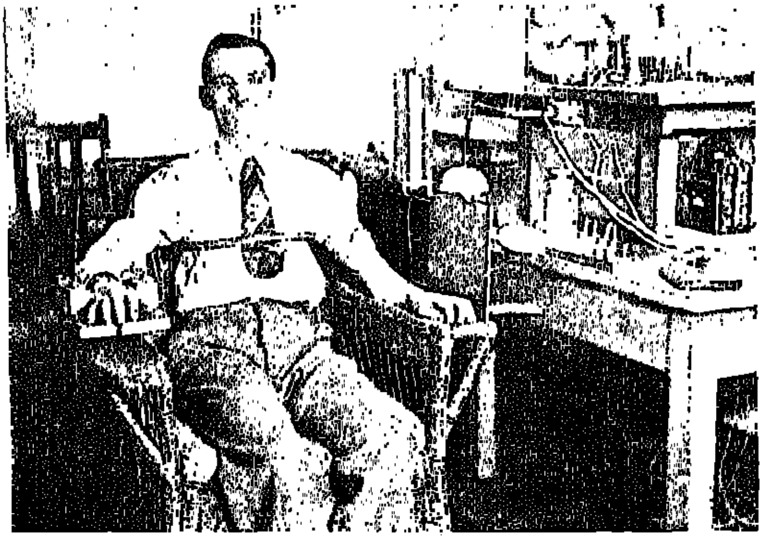
Records of physiological changes and times of application of stimuli were made on a modified Ohio State Polygraph (52). Samples from typical records appear on page 230. A complete description and analysis of polygraph records appears below in Section G. The paper was driven by a constant-speed motor at the rate of 14 centimeters per minute. The distance between deflections on the time line operated by a 1-second pendulum offered a ready check on the constancy of paper speed. Pens were all of the Inkograph type except those used for the breathing and blood-pressure records—these latter were small capillary pens attached to tambours by means of aluminum strips. The essential features of the polygraph may be seen in Figure 1 B.

The transverse alignment of the pens making the breathing and blood-pressure records was approximately 4 centimeters to the left (in front in regard to time) of the transverse alignment of the other pens. This was necessary because the total excursion of all of the pens used was in excess of the width of the paper, viz., 8 inches, and also because the capillary pens were dropped perpendicularly from the tambours, which were too large to be mounted in the bridge supporting the other pens. Thus the eight pens in the bridge recorded coincidentally, but the time of the capillary pens was ahead of that of the other pens. By use of irregularly shaped templates, in reading the records comparisons could be made of reactions occurring simultaneously (cf. *infra*, Section G).

Photographs of the apparatus appear on the immediately following pages. These have been placed together to facilitate reference to them. In the following short description, all references to right and left will be to the reader's right and left. A more complete description of some of the photographs will appear in the section in which the apparatus pictured is discussed. Figure 1 A shows almost the entirety of the experimental room. The projection machine for moving-picture films is seen in the left background, with the subject's chair to its right. To the right of this is the polygraph table, and in front of this is the table used for accommodating the materials used in obtaining saliva samples. B in Figure 1 shows a subject seated in the chair, with right arm in the planchette, thoracic pneumograph and blood-pressure sleeve attached. The manometer is on the edge of the table to the right of the chair, and the top of the pressure-reducing device is to the right of this. Figure 2 A shows a close-up of the manometer and pressure reducer, and syringes and sample bottles. B, Figure 2, shows the calomel half-cell used in the electrometric titrations. The sample bottle, which served also as electrode vessel, is seen slipped up around the platinum-wire electrode and glass tubing. The wire connections to right and left lead to the potentiometer.



A



B

FIGURE 1

B. RESPIRATION

The ordinary type Sumner pneumograph, a rubber tube with a spiral spring inside, was used. In the preliminary studies both abdominal and thoracic breathing were recorded. A very uniform record of abdominal breathing was presented by every subject so it was eliminated in the experimental records. The curve for abdominal breathing was practically a straight line with most infrequent deviations. A probable explanation of this is the fact that all subjects were instructed to sit well back in the chair and to maintain an erect position, thus greatly minimizing the excursion of the abdominal wall in breathing.

The pneumograph was always fastened approximately in the same position—the rubber tube passing across the sterno-costal angle anteriorly and the chain passing just below the inferior margins of the scapulae posteriorly, with the tension about the same each time. The subject was asked to remember just how the pneumograph felt and to instruct the experimenter in placing it subsequently. A T-tube with clamp was inserted in the pneumatic line between the pneumograph and tambour for adjustments. The open end was clamped off in each instance so that at the end of the expiratory phase the rubber dam on the tambour was almost completely collapsed. This tended to render breathing curves comparable. All pneumatic connections were made with glass tubing of 5-millimeter inside diameter. New rubber dams from a fresh stock of thin dental dam were stretched uniformly on the tambours three times per week. Each subject wore the pneumograph for two half-hour periods before the experimental series was begun so that some adaptation might take place. In order further to insure comfort the plates of the pneumograph were placed over the mid-axillary line on each side. A wicker chair with recessed back was used so that the chain was not pressed against the subject's back. Full excursion of the chest wall was facilitated by the position of the subject's arms—the right arm slightly extended from the body in order that it might rest in the planchette, and the left arm slightly extended to rest on the chair arm. Adaptation to the pneumograph was rapid, and, since each subject served from 10 to 25 experimental periods, the hampering effect of the pneumograph was almost negligible in the principal series. A full breath at the beginning of each experimental period indicated the maximum excursion on the polygraph record.

C. Blood Pressure and Heart Rate

Continuous blood-pressure records were made possible by a device which permitted the obtaining of blood-pressure changes with a very small amount of pressure in the sleeve worn on the arm. This pressure reducer was built after suggestions by Edwards (26), with considerable modification and alteration.

It is shown in Figure 2 A. It consists of two air chambers separated by a rubber diaphragm over which metal discs with different-sized holes may be placed. The purpose of the discs is to adjust the pressure in the two chambers so that the critical pressure of the

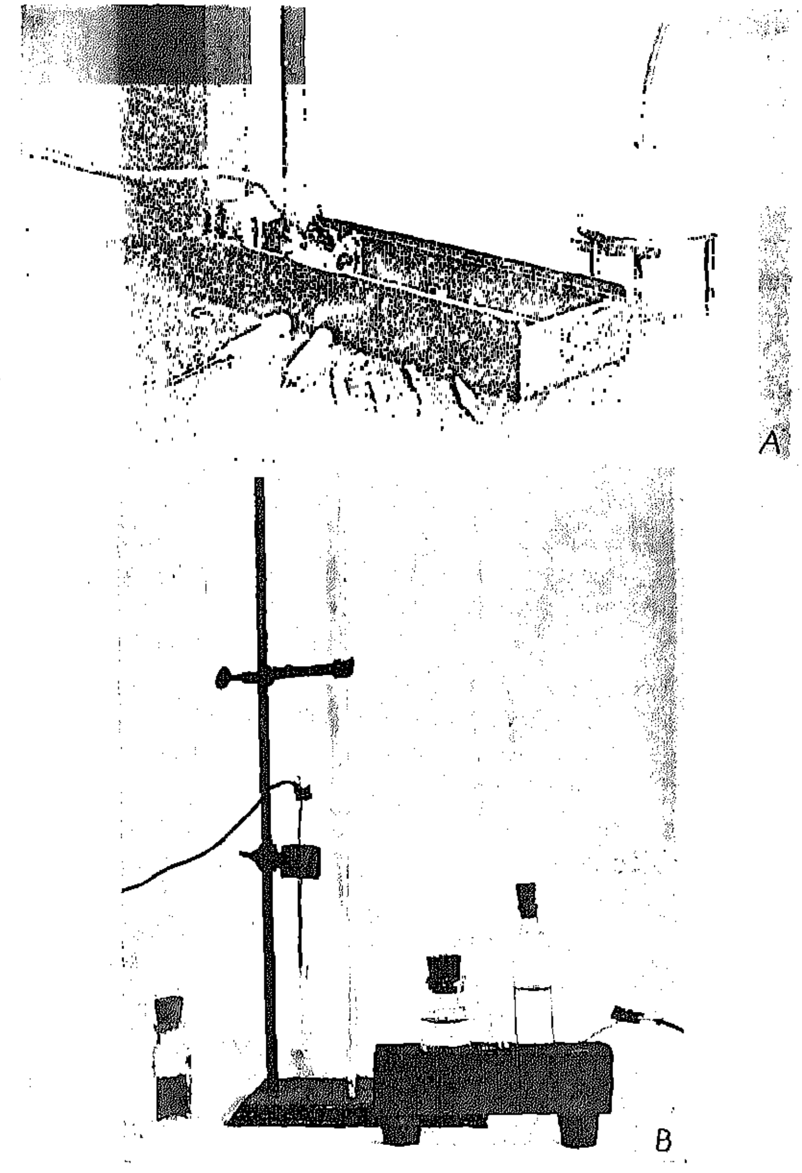


FIGURE 2

air in the low-pressure chamber, which is the upper chamber, is just approached. If we think of the second-degree curve showing critical pressure in a gas, with volume on the ordinate and pressure on the abscissa, the critical pressure of the gas is the higher inflection point. Thus, if the pressure and volume relationships in the two air chambers are properly adjusted (this is done by means of the discs which allow definite areas of the rubber dam to be distended) a small change in one air chamber produces a larger change in the other air chamber. A correspondingly small change in pressure in the high-pressure chamber will cause a correspondingly large change in the volume of the air in the low-pressure chamber which may be transmitted in a closed air system to the tambour and thus recorded on the polygraph paper. A pressure of approximately 32 millimeters of mercury in the blood-pressure sleeve was sufficient to give a blood-pressure record in which rather small changes were readily discernible on the polygraph record. The high-pressure chamber was connected to a T-tube; one arm of the T being connected to the manometer and the other arm to the blood-pressure sleeve on the arm of the subject.

With this very small pressure of 32 millimeters in the sleeve subjects could wear it in experimental periods of one hour without discomfort. In the preliminary studies, three subjects served for periods varying from two to two and one-half hours and reported no discomfort from the pressure on the arm. Some records in the preliminary studies were made with the sleeve fastened on the left leg, just below the knee, but for various reasons the sleeve was fastened on the left arm in the main experimental series. Rubber dam in the pressure reducer was changed three times per week, and each piece was put on in approximately the same way and stretched with the same degree of tension.

An improved type desk model of the B-D physician's manometer was used. This seemed to serve best; and it is also carefully checked by the manufacturers at various pressures. A standard sleeve was used—cloth-covered rubber bag, with a small rubber bulb with appropriate valves for inflation and deflation of the sleeve. The sleeve was put on next to the skin of the left arm just above the elbow, and inflated to about 50-millimeters pressure because a clearer heart-rate record was obtainable at this pressure. Pressure was then reduced to 32 millimeters, with an increase at intervals for the reason mentioned above. A careful attempt was made to discover any pathological conditions in heart action or respiration by questioning the subjects regarding medical history and by physical examination. Actual systolic and diastolic blood-pressure readings were also made at intervals throughout the time during which the subjects served. Heart rate was also counted occasionally as a check on the polygraph record of that reaction. In this way any pathological defect previously reported could probably be substantiated. It was planned to have a physician check any pathological defects which showed up in our records, but no such instances appeared, with a few minor exceptions.

The records, then, showed rises and drops in blood pressure, some function of systolic and diastolic pressure,[4] and heart rate by the recording of separate pulsations in the record. Persons with correspondingly high pulse pressure enabled the experimenter to get continuous records of heart rate, but those individuals with rather low pulse pressure afforded heart-rate records only when the pressure in the sleeve was increased to something above 32 millimeters. At this pressure, the amplitude of the deflections depicting pulse rate was perceptibly increased.

Analysis of the records was comparable in each instance because of the standard pressure in the sleeve and the attempt to standardize the conditions of elasticity in the rubber diaphragms used in the pressure reducer and tambours. All pneumatic pressures were transmitted through glass tubing to avoid distention of walls in rubber tubing.

D. ARM MOVEMENTS

Arm movements were recorded from a planchette suspended from the ceiling. Stop-blocks made it possible to adjust the surface to accommodate the width of the subject's right forearm, and also to keep the arm stationary in relation to the planchette. The arm was placed palm downward, with support the full length from the elbow to the fingers. The 8-foot length of the suspending wire greatly minimized vertical movement due to the arc. The level of the planchette was the normal level of the arm of the chair. Each subject was instructed to place his arm on the wooden platform as if it were the arm of the chair, and let it assume a normal position. A standardization of position for each subject was attempted from the pre-experimental notes. Since the sitting posture was the same and trunk height and arm length determine to a great extent arm posture, this standardization was effective.

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[4] Larson interpreted his records as roughly two-thirds of systolic divided by one-third of diastolic. He used about 40- or 50-millimeters pressure in the sleeve.

At the beginning of each experimental series, the first thing the subject did after sitting down was to put his arm on the planchette. Then the pneumograph was put on, likewise the blood-pressure sleeve, the polygraph was started, a saliva sample taken, and various other adjustments made. Total time for the above varied from 4 to 10 minutes. Finally the planchette was attached to the polygraph pens. In this way a more natural arm posture was assumed, and, because of the lapse of time and the direction of attention to other things, we infer that the posture was fixed consciously by the subject in very few instances.

Silk thread, which was rather easily broken, connected the planchette with mechanically operated polygraph pens. This fine thread served as a safety valve —it broke with violent movements before injury was done to the polygraph. Thread was conveyed around corners by means of wire angles, which offered a negligible amount of friction as compared with pulleys. These angles were pivoted at the apex at points of directional change, and excursions within the limits of the throw of pens were transmitted undiminished and unaltered. The angles were actually isoseles right triangles made of No. 14 copper wire, hinged by means of a brass bearing at the right angle. Two of these angles may be seen mounted on the polygraph table in Figure 1 B. The pathway of the thread, one for proximal and distal movements and one for right and left movements, may be traced in Figure 1 B. Four angles occur in each path.

When the planchette was attached to the pens, each pen was set at the center of its throw (total excursion 1⅞ inches) so that movements were recorded as deviating from a normal "rest" posture. Deviations of two sorts were ascertained from the records, viz., deviations from the base line of the arm-movement line, and total excursions from another base line independent of the first base line. (Cf. *infra,* Section G, "Analysis.") Mechanical pens recording arm movement were counterbalanced with spiral springs of light tension, so that from the center of throw all shifts in arm posture were recorded—movements of 1 millimeter showing plainly on the records. Both slight and violent movements were recorded, and comparatively few occurred which were in excess of the pen excursion. The device resolved all motions of the arm in the horizontal plane into two components, and the magnitude of the excursion of the line on the tape was identical with the actual excursion of the arm.

E. HYDROGEN ION CONCENTRATION OF SALIVA

From the preliminary studies and considerations, and from the previous results obtained by analysis of various body fluids, salivary pH was selected as the most profitable of such fluids for this investigation. Samples of saliva are readily available, and taking them causes no discomfort to the subject, as does the taking of blood samples, for instance. Adequate means were developed for most accurately determining the hydrogen ion concentration of very small samples of saliva.[5] The big difficulty encountered but overcome in the preliminary studies was that of obtaining and preserving the sample.

For the purpose of obtaining the samples we used ordinary hypodermic syringes. A 5-cubic-centimeter syringe made of pyrex glass, equipped with a 20-gauge silver needle 2 inches in length was used. Points on the needles were ground off and rounded. This syringe could then be inserted into the subject's mouth and the saliva sample taken from the same place each time, without causing the subject to part his lips or turn his head. Preliminary trials were run so that the obtaining of a saliva sample became a routine matter and the distraction greatly minimized. Syringes and needles were sterilized by boiling for 5 minutes in a very high grade of distilled water (cf. *infra*) to avoid any chemical contamination. Allowing saliva samples to remain in the syringe for a time and then checking small portions of the sample indicated that the hydrogen ion concentration was not altered by contact with the syringe or needle, and that the method of sterilization also did not influence subsequent samples. No chemical agents were used in sterilization. Solutions of known pH were also drawn into syringes and checked. No significant changes occurred. Reliability of the method of preserving samples was also checked and found to be highly satisfactory.

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[5] Acknowledgment is made to Professor G. M. McClure of the Soils Department, Ohio State University, for aid and advice concerning the determination of hydrogen ion concentrations of saliva samples and for use of equipment.

The syringes overcame any difficulty presented by an object in the mouth, such as a saliometer or tube, and also prevented contact of saliva sample with the air. This latter difficulty is quite pronounced in the use of a loop or similar device, which causes relatively large changes in pH when the sample is passed through air.

The next problem was that of preserving the samples until pH determinations were run. It was, of course, necessary to transfer these samples to some kind of an electrode vessel before potentiometric titrations could be carried out, and also necessary to have some container for the large number of samples taken during an experimental period. In some periods lasting 45 minutes, as many as twenty samples were collected and these, of course, had to be measured at a later time. A special sample bottle was developed with the aid of Professor McClure. It was desirable to use the sample bottle also as an electrode vessel to obviate the necessity of transferring the saliva from a sample bottle to an electrode vessel and thus have the saliva come in contact with air. Several types were made up for preliminary study. Pyrex glass was, of course, necessary to avoid the alkalinizing effect of ordinary glass on liquids. Several sizes were tried, and the bottles 1 inch in height, slightly under 5/16 of an inch in inside diameter, with a round bottom, were selected. For a cover, rubber caps, marketed commercially as "Rubber Policemen" were used. Ground-glass stoppers were fitted to some of the first sample bottles, but the rubber caps preserved samples just as well, and the necessity for keeping two or three hundred bottle-and-stopper combinations intact was obviated. The size of the bottle was determined largely by the size of the electrode and bridge which dipped into it when used as an electrode vessel, and by the facility with which the bottle could be cleaned and made ready for further use.

Samples were identified by being placed in numbered holes in a drilled-board rack. Sample bottles were kept, cleaned and dried, in a large glass-stoppered bottle, and the caps kept in a similar way, so that, as the syringe containing the saliva was taken from the subject's mouth, a sample bottle was taken from the clean supply, the needle placed in the bottle, the sample expelled by pushing the plunger down, and the cap put on immediately. Exposure of the saliva to air was only momentary.

Specially treated triple-distilled water was used to clean sample bottles, caps, and syringes. The triple-distilled water was put into a paraffin-lined pyrex flask, and a suction pump forced air through which was drawn over soda lime. The same flask, equipped with a soda-lime tube served as a storage flask. Fresh supplies were treated three times per week.

After taking each saliva sample, the syringe and needle were rinsed three times by drawing in and expelling 2 cubic centimeters of the treated distilled water. Sample bottles and caps were rinsed several times in the same kind of water, boiled for 15 minutes, then rinsed individually and dried.

For the pH determinations, a modification of Biilman's (21) quinhydrone[6] electrode was used. This was selected as being most convenient and readily usable with samples as small as two drops of saliva. The quinhydrone half-cell has been standardized by Biilman and adopted by a very large number of investigators in this country as a most excellent device for determining hydrion activity.

The electrode used in this study was platinum. The saliva was saturated with quinhydrone. To complete the cell, the quinhydrone half-cell was put in liquid junction with a calomel half-cell. The electrode quinhydrone half-cell (sample bottle) and calomel half-cell are shown in Figure 2 B. The formula for quinhydrone electrode observed potential appears on page 405 in Clark (21). The potentiometer used was the Leeds and Northrup, Type K. A complete description with wiring diagram appears in Leeds and Northrup *Bulletin* No. 755. A galvanometer manufactured by the same company as No. 2420 was used. A Weston Standard Cell served to balance the galvanometer, and 2½-volt dry-cells were used for current source. A double-pole double-throw switch was inserted in the "E.M.F." line to the galvanometer, from the electrode and calomel cell, so that polarity could be reversed to accommodate for the reversal above 7.68 pH without actually changing connections at the potentiometer binding posts.

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[6] Quinhydrone is a complex formed of equimolecular proportions of quinone and hydroquinone.

The technique of potentiometric titrations is thoroughly explained by Kolthoff and Furman (35). A table was made up for use in determining pH values from observed voltages. An easily added or subtracted temperature factor made the table quite valuable and very easy to use.

At the beginning of each period during which the hydrogen ion concentration of saliva samples was measured the platinum electrode was thoroughly cleaned in boiling potassium bichromate and concentrated sulphuric acid solution, rinsed in distilled and triple-distilled water, and finally heated to redness in an alcohol flame. Tube and electrode were placed so that the sample bottle could be slipped up around them. The sample bottles adhered because of capillarity. The electrode and tube were rinsed between each measurement, and the galvanometer was balanced with the standard cell before each reading. Between determinations of each group of five samples, readings were made on a carefully prepared 1/20 normal potassium acid phthalate solution. Thus a convenient and frequent check of the potentiometer and electrode system was obtained.

The minimum amount of quinhydrone was determined in the preliminary studies, but an excess was not critical. Potentiometer readings were obtained in slightly less than 2 minutes after the cap was removed from the sample bottle and the quinhydrone introduced. After the determinations, the appropriate values of pH were written in, at the point indicated by the signal mark, on the polygraph records.

F. THE STIMULI AND STIMULUS SITUATIONS

During the experimental periods, the doors and window in the 19 x 10 experimental room were kept closed. The room was situated so that corridor noises were minimal. For most of the experimental periods, the daylight entering the window was the only light source. During the winter, one 100-watt bulb in a ground-glass globe placed in the center of the ceiling was kept lit. When moving pictures were shown, the room was darkened.

Conditions during experimental periods were fairly constant. Most appointments with a given subject were at the same time of day so that previous classes, work, meals, etc., would be constant.

After each subject had spent two half-hour periods in the chair with apparatus attached as is shown in Figure 1 B, and had become accustomed to having saliva samples taken, the next few experimental periods were used to obtain normal rest records. The number of these rest periods averaged eight for each person. The periods themselves lasted from 30 minutes to 1 hour. (Two-hour records were obtained in the preliminary studies.) The experimenter stayed in the room at all times and obtained saliva samples at intervals. Of course, the first and last part of every record, even those obtained in periods in which special stimuli were used, were actually a type of rest record, since the subject always sat quietly at the beginning and at the end of each period.

The experimental periods in which special stimuli were used were designated Experiment 1, Experiment 2, etc., for purposes of handling the records, so they will be discussed below under that classification. In most cases they were presented in order, following the initial rest periods.

Experiment 1 consisted of having the subject follow directions in reading a page of figures. This page was an 8½ x 11-inch sheet with 24 rows of figures, 53 digits in each row. The subject was instructed to read each line from left to right and mentally cross out each seven. The sheet was affixed to a holder which was put in front of the subject's chair at the proper time. The holder was adjusted to the reading position, since the subject could not move his hands to hold it, one of his hands being placed on the planchette and the other on the chair arm with blood-pressure sleeve attached. Arm movements and even gross muscle contractions while the position of the arm remained the same were avoided. The beginning of reading, midpoint, and end were indicated on the polygraph record at a nod from the subject. The holder was removed and a 6-minute rest period ensued. Then the sheet was replaced, this time the subject being instructed mentally to cross out the five's and encircle the three's. Beginning, midpoint, and ending time were transmitted to the record tape in the same way. After another 6-minute rest period with the holder removed, the subject was instructed to add, mentally, the first five digits in each line, telling the experimenter when the midpoint and end were reached. This completed Experiment 1.

The purpose of Experiment 1 was to elicit the subject's attention and to obtain a record while he was engaged in a form of mental work. We were not concerned with the accuracy or speed of his performance. This was designed also to serve as an intermediate or transitory situation from which we could lead into the experiments in which stronger stimuli were used, the purpose of which was to arouse emotional reactions. Some measure of the physiological reactions in a situation different from a normal rest period was desired before records were made in experiments involving fear stimuli, for instance. It should thus be possible in the more crucial experiments to separate the results due to actual emotions from those caused merely by more definite occupation of the attention.

It should be noted here that in Experiment 1 and in Experiment 2 no saliva samples were taken during the actual reading of the pages. Samples were taken before and after the reading.

For Experiment 2, a short story, one page in length, was affixed to the same holder as was used in Experiment 1. This was put in reading position and the subject told to read it in the same way that he would have if he had turned to it in a magazine. The subject read straight through the page, and nodded when he was one-third and two-thirds of the way through and finished reading. Times of beginning and ending and the intervening points were recorded on the polygraph paper.

A brief synopsis of the story follows: The scene is a cabaret, with a middle-aged man offering a girl a string of pearls on the condition that she "return." A sleek-haired young man enters the room during this conversation, and remarks about him are made by the principal characters. Finally, after much pleading, the girl decides to return, and tells the middle-aged man, who is really her father, that he needn't tempt her with the family jewels to persuade her to give up her very short career as a cabaret dancer. This story was selected for its abrupt and surprising ending. Average reading time for this story was slightly under 4 minutes. Subsequent questioning of the subjects showed the ending to be a complete surprise in every instance.

Experiment 2 was designed to afford a rather mild emotional excitement, but its especial features were abruptness and surprise. Physiological reactions were recorded during and after the reading, and the persistence of changes could, of course, be ascertained. As mentioned above, saliva samples were taken before and after the story was read.

Experiment 3 was one of the crucial experiments in which fear stimuli were used. A most effective stimulus was the western bull snake. The snake measured 6 feet and 4 inches in length. It was presented to the subjects, without warning, in the following manner: At a prearranged signal an assistant released the snake just outside the door of the experimental room. This door was in front of and to the left of the subject. The snake was pushed in such a way that he crawled out into the room about 12 feet in front of the subject's chair. The snake was handled somewhat roughly before his entrance so that he moved into the room rather quickly. During this procedure the experimenter remained at the rear of the subject's chair, and came around in front only to take saliva samples. After a period of about 4 minutes, during which the snake usually crawled slowly about on the floor in front of the subject, the assistant came into the room to get the snake. Ostensibly, the "scare" was to be over at this point. Then, as the assistant[7] attempted to catch the snake with a stick and a box, an "escape" was staged. The assistant excitedly warned the experimenter not to let the snake get too close to the subject. In attempting to pick up the animal, his tail would be twisted in such a way that he would dart forward rapidly and he usually approached within a few inches of the subject before he was "captured." After the snake was picked up, it was contrived to have his head swing very close to the subject's body, and then the snake was removed. This part of Experiment 3 occupied from 4 to 8 minutes.

It is felt that in this situation any artificiality of a "laboratory fear stimulus" was overcome. When the snake first appeared, the subject was momentarily frightened, but most of them reported subsequently that they felt we would prevent any actual harm. But this reassurance vanished when the "escape" was staged. The subjects felt then that conditions had got beyond the experimenter's control.

The other stimuli in this experiment were the sound of a Klaxon, firing blanks in a 38-caliber revolver, setting off a flash just in front of the subject, and pulling a resin-treated cloth over a string attached to the bottom of a 4-inch tin can. All of these stimuli were presented without warning. The Klaxon was concealed behind a radiator to the rear of the subject's chair and was operated from a concealed switch. The flash was also operated by a concealed switch. This flash was produced by shorting 110-volts through a small piece of 3-ampere fuse wire, attached to binding posts mounted on a small asbestos platform behind a piece of plate glass mounted on the edge of the platform nearest the subject. This served quite well, giving an intense flash, and also avoiding the olfactory stimulation accompanying a magnesium flash. It was completely reset for later use merely by affixing another piece of fuse wire. The revolver was fired out of view of the subject. Thus all of the stimuli were presented in abrupt ways, the time of presentation or the nature of the stimulus being completely unknown to the subject. The order of presenting the stimuli was varied. In many instances the Klaxon was sounded and the gun fired both before and after the entrance of the snake. Comparisons of the effect of shots before and after the presentation of the snake showed an interesting increase in response to the later shot (cf. Chapter III *infra*).

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[7] In most instances the assistant was Dr. H. E. Burtt. Most of the subjects, after they were told the truth, loudly praised his histrionic ability.

The polygraph record was appropriately marked by the signal pens. Saliva samples were taken at fixed times, e.g., before and after the presentation of each stimulus, with several taken while the snake was in the room, one of them usually just after the "escape."

Samples were also taken, of course, during the initial rest period and after the subject had been told that there would be "no more scares today."

The other crucial experiments were those in which moving pictures were used. A small screen, 4 feet square, was mounted on the wall in front of the subject's chair and was about 14 feet distant. The size of the projected picture was just within the limits of the screen. The screen was placed with the lower edge about 3 feet above the floor so that the pictures were projected at the eye level of the subjects in sitting posture. Thus the subject did not have to change the position of the head when viewing pictures and consequently no change in body posture was necessary. Blood-pressure sleeve, planchette, and pneumographs were in the same position, with the same muscular tension, as they were in other experimental periods. Records were obtained with the subject in approximately the same position that he was in during the other experimental periods. The only changes within the room were those occasioned by lowering the window shade and the slight noise of the projection machine.

The projection machine occupied a position to the right and slightly to the rear of the subject. Its position may be seen in Figure 1 A. A machine of this type was necessary since the film used was standard size. A telegraph key mounted in parallel with the key used as the stimulus signal for marking polygraph records was mounted on the projection machine, so that records could be marked appropriately during the showing of a film.

Seven reels were prepared and edited, but the records obtained from only four of them are included in the present study. These four reels will be described.

Experiment 10 involved a news reel made up of various scenes. Total time for projection was 10 minutes. It contained in the order named: dog-sled race with presentation of cups to winners at finish; Japanese fire department field-day exhibition; ice-covered fishing vessels returning to port; depiction of stone-block cutting in Italian marble quarries; and, finally, a winter carnival showing fancy ice skating, with close-ups of champions in action. Polygraph records were keyed at the beginning and end of the film; saliva samples were taken before and after the showing of the film.

This film was used as the control moving picture. No highly exciting scenes were included. It was thought that the records of physiological reactions during the showing of this film might serve as a basis for evaluating reactions when the more exciting films were used. Also, the effect of the total situation of projecting films, if such an effect occurred, would be apparent in the comparisons of normal rest records and records obtained in Experiment 10. In succeeding experiments in which more crucial moving pictures were used, allowance could be made for this normal film effect.

Experiment 10 usually constituted the sitting following Experiment 3 (fear and shock stimuli), although occasionally a rest period intervened. Experiments 11, 14, and 16, to be described presently, then followed Experiment 10 in the order listed.

Films used in Experiments 11, 14, and 16 were made up of several shorter sections of film cemented together. The total times of projection were: Experiment 11, 8 minutes and 50 seconds; 14, 5 minutes and 20 seconds; and 16, 7 minutes and 30 seconds.

The film used in Experiment 11 consisted of excerpts depicting the following things in the order named. A group of young ladies wished to go swimming but had no appropriate apparel. By using "trick" photography, these girls walked behind trees, fully clothed, and emerged immediately on the opposite side in bathing costume or went through other transformations. Dancing contests on a beach. Several close-up views of oriental dancing followed. There were further silhouette pictures of two girls dancing on the beach, with the setting sun in the distant sky as the background. Next came a review of bathing beauties. Some fifteen individuals passed slowly in front of the camera. A child in a policeman's uniform passed in front of the line of bathing beauties, looking them over. A portion of a World Series baseball game was presented. Views were included of the spectators, a governor pitching the first ball, close-ups of pitchers, a prominent baseball hero batting and running to first base. Next were crowds entering a stadium to witness a heavy-weight boxing championship contest, with several views of the contest. Then came a subtitle stating that pictures of the actual fight could not be shown because of federal laws.

The type of stimulation offered by this film was varied and the shifting of scenes was rather rapid. The types of emotional stimuli offered might be classified roughly in this way: Certainly some sex interest would be shown in the bathing beauties by the male subjects. The female subjects, of whom there was a considerable number of physical education majors, would probably appreciate or admire the dancing technique. Subjects of both sexes would be surprised at the changes in the "trick" photography scenes. A rather beautiful scene of a sunset over an ocean beach might arouse an aesthetic attitude in subjects of both sexes. (Protocols substantiate this.) The child in policeman's costume was "cute" to many subjects. Baseball game and boxing match scenes appealed according to the sports interests of subjects. When we originally selected moving pictures for use as stimuli, it was hoped that complete social situations might thus be presented to the subjects. Some of the subjects reported after seeing the films that they had "entered" into the situation and had felt as they did while actually attending these events. This illusion was probably strengthened by the fact that some popular idols were characters in some of these films. The announcement that no actual pictures of the boxing match would be shown served as a disappointment to most of the subjects, by their own report. This same announcement, however, was a "relief" to several women subjects who had no desire to witness a boxing match. The film was stopped at this point for most of the subjects. A boudoir scene followed and was presented to a few mature male subjects. This last scene afforded an abrupt change in emotion from that aroused by the fight just preceding.[8]

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[8] For this group of subjects, an extra saliva sample was taken, viz., before the last scene of the film.

The film in Experiment 14 contained these scenes: a rather naïve and ungainly sailor was approached by a South Sea Island girl, with the motif of the scene strictly comedy rather than sex. Then a stage-coach hold-up and gun battle with the scene shifting to the street of a small frontier town. Men were being shot and falling from roofs, out of trees, etc., in rapid succession. Flashes were shown of groups firing from behind barricades of tables and chairs. The action was rapid and violent, a typical "Western Super-Thriller," only worse. It presumably would arouse excitement and also reveal the differences in the reactions of the sexes to this type of situation. Then came a cabaret sceen in which a young lady is embarrassed by seeing her father in an embarrassing situation. This scene was selected to arouse disgust in both male and female subjects, with consequent pity for the plight of the daughter. The subjects' reports indicate that this situation was reacted to in the manner in which it was intended. This film ended with a rather lengthy scene of a popular moving-picture actress dancing before a sultan. There is an elaborate setting and technicolor photography. As the scene ends, the dancer is borne from the throne room on a litter carried by eight shining black slaves. There were no repulsive elements in this scene for either sex.

In Experiment 16, the film depicts a beautiful mountain stream with a canoe drifting leisurely; some backstage views of a vaudeville theatre; an argument between two actors; a lengthy embrace; and a series of short views of very prominent and popular moving-picture stars in various situations. These last clippings were selected for the types of facial expression portrayed by the popular actors. One was clearly surprise, another shame, and another appreciation of beauty.

The excerpts included in the films described were all taken from current films which have proven successful as theatre attractions. All of them were from films which had not been shown to the public in this section of the country or were censored "clippings," so that they were new to the persons serving as subjects in this study.

The shifting in scenes was recorded on the polygraph records by a series of coded dots and dashes. Saliva samples were taken before the projection of films, and following the projection. Ten samples were taken during Experiment 11, five before the film was shown, and five after the film was shown. Samples were not taken during the showing of films, since the experimenter would have to stand in front of the subject and thus occlude the view of the screen.

G. ANALYSIS OF THE RECORDS

Reading and analyzing the polygraph records presented several problems. Methods of taking measurements and interpretation of the data were developed by some preliminary investigations. Some of the points considered were the extent to which various aspects of the functions measured seemed most differential and the means of interpreting breathing and blood-pressure variations used by previous investigators. It was necessary, of course, to sample the records, and the size of the samples to be measured in each record was a moot problem. Quite obviously, records could not be measured in their entirety, both from the standpoint of the time which would be necessary, and also because such a procedure would give an unwieldly mass of data. The final determination of the size of the sample was made by measuring several samples of different sizes. Such samples were measured in normal rest records for six individuals, and on the basis of variability shown in the measurements made on these records, a 1-minute sample was found to be adequate. An additional reason for selecting a sample of this size was the argument for small samples proposed by Fisher (28). Fisher and others have shown rather conclusively that a closer approach is made to the true mean in biological data by taking a larger number of small samples than by a smaller number of large samples. It was decided thus to use 1-minute samples, selected so as to give a random and unbiased sampling of the record.

At the speed at which the polygraph paper moved, a 1-minute interval occupied exactly 14 centimeters. Samples were marked off by a celluloid template. Alignment was insured by a standard way of superimposing the template. The outline made by this template may be seen in the record shown in Figure 3 A.

For the analysis of the breathing curve some measure was desired which would show the maximum excursion of the chest walls in breathing. This was obtained from the difference between the highest peak and the lowest trough on the breathing curve. Measurements were in millimeters from a fixed base line. Differences were expressed as actual arithmetic differences.

Breathing rate, or frequency, was the number of peaks on the breathing curve within the sample. The number of atypical breaths occurring in the sample was also noted. These were judged solely by inspection, and counted. By observation the typical trend in the sample was determined, and any deviation from this in terms of amplitude or length or form of the wave was designated atypical. (Notation in Figure 3A—*ef* and *gh*, measurements from fixed base line to *B.P.* line; *ij*, measurement from fixed base line to lateral movement line; *kl*, measurement from fixed base line to longitu-

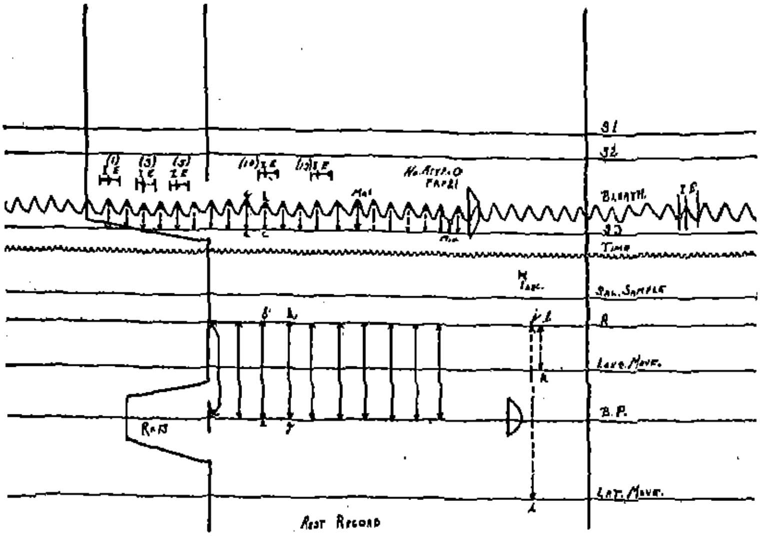

FIGURE 3A

dinal movement line. The heavy outline is made by the template. Extensions for the breathing and blood-pressure record are due to the fact that the two pens in question were set ahead of the others as explained above. Other notations are self-explanatory.)

In order to get a measure of variability in depth of breathing, distances from the fixed base line were measured in millimeters to each peak in the curve. Standard deviations were then to be computed for these measurements.

Inspiration and expiration times were measured for the first, third, fifth, tenth, and thirteenth breaths in the sample. These were selected to give an adequate sampling, since the rate was generally something under 20 per minute, and also to give an unbiased sampling. (It very often happened that the breaths showing the greatest variability in the crucial experiments did not include the five selected to be measured. Thus variability in inspiration-expiration ratios was not strictly comparable with that in the other measures of breathing.) These inspiration and expiration times were measured in terms of linear distance to half-millimeters. A perpendicular was constructed from the base line through the lowest inflection point on the breathing curve at the beginning of the upstroke. Another perpendicular was drawn in the same manner at the highest point on the curve. The distance between these represented the time of a complete inspiration from its beginning to its end. The distance from the last-mentioned perpendicular to another placed at the point at which the breathing curve again started to rise was the linear equivalent of expiration time. (Figure 3 A.) Inspiration-expiration ratios were then determined for each breath. These five ratios were then averaged.

On the blood-pressure line the maximum rise, as well as the maximum drop, in blood pressure was determined. These deflections were measured, in terms of fiftieths of an inch from a fixed base line—the line made by the pen marking response signals. The units of measurement were selected so that very small deviations in blood pressure would be taken into account.

It was hoped that in this way relatively slower and more gradual rises and drops would appear also. When these occurred they were apparent in the measures designed to show variability, which will be described presently. The numerical difference between maximum rise and maximum drop was noted. This expressed the greatest deviation in blood pressure within the sample. The duration of each rise and the duration of each drop was measured in terms of linear equivalence. In this way sudden rises or drops could be classified as distinct from rises occupying a longer time. Also, it could be determined whether a stimulus which occasioned a rise in the blood pressure of an individual would cause this rise to persist for any appreciable time. The duration of a rise or drop was measured from a preceding horizontal section to a following horizontal section, or to a return to a normal. This return to normal was not necessarily the normal blood pressure for that individual, but was normal as compared with the immediately preceding section of the line. The criterion of "normal" in this instance was a level portion at least 6 centimeters in length. The number of sharp peaks in the blood-pressure line within the sample was also noted.

To obtain a measure of variability, distances from regular points on the fixed base line to the blood-pressure line were found. Ten of these measurements were taken in the sample, at points 1 centimeter apart. The first was taken 2½ centimeters from the beginning of the sample and the last one 2½ centimeters from the end of the sample, with the perpendicular distance from the base line to the blood-pressure line being measured at 1-centimeter intervals within these limits. Thus, within this portion of the sample, a measurement was obtained every 4.3 seconds. Standard deviations of these measures could then be computed as expressions of variability. Heart rate was counted from the small deflections on the blood-pressure line caused by heart beats. This count was made within a 35-millimeter section at the beginning of a 1-minute sample. This was not always discernible within the 1-minute sample, but might be obtained outside the sample. This was due to the fact that the pressure in the sleeve had not been increased at a point just preceding the sample, so that individuals with a low pulse pressure gave no heart-rate record. In situations of this kind, heart rate was taken outside the sample if it was available within the preceding 30 seconds, i.e., the preceding 7 centimeters of the record. Otherwise, no heart-rate score for this sample was obtained.

Arm movements were analyzed from several aspects.

The longitudinal or proximal and distal movements and the lateral or right and left movements were treated separately. The frequency of movement was obtained by counting the number of changes in direction of the line-recording movement. The total time of movement was measured in terms of its linear equivalence. That is, if a section of irregular line appeared between two sections in which there were no irregularities, *this linear distance of the irregular portion gave* the time during which there was movement. These times were cumulated within a given sample to show the total time of movement.

The maximum single excursion occurring in the sample was measured from the rest, i.e., the level portion of the line just preceding the deflection. The criterion of "just preceding rest" was a portion of the line 2 centimeters in length in which there were no changes of direction. The maximum and minimum *distances from a fixed base line were also measured.* The line taken as this base was the response signal line. The arithmetic difference between maximum and minimum distances from this base line expressed the variation in movement within the sample.

The pH readings were written in on the polygraph records at the places denoted by the appropriately keyed marks (cf. *supra,* Section E). These values were classified as pre-experimental, experimental, and post-experimental in all of the records except those for *normal rest periods. The linear distances between* these samples gave the actual time between them. The pH values were treated as functions of difference.

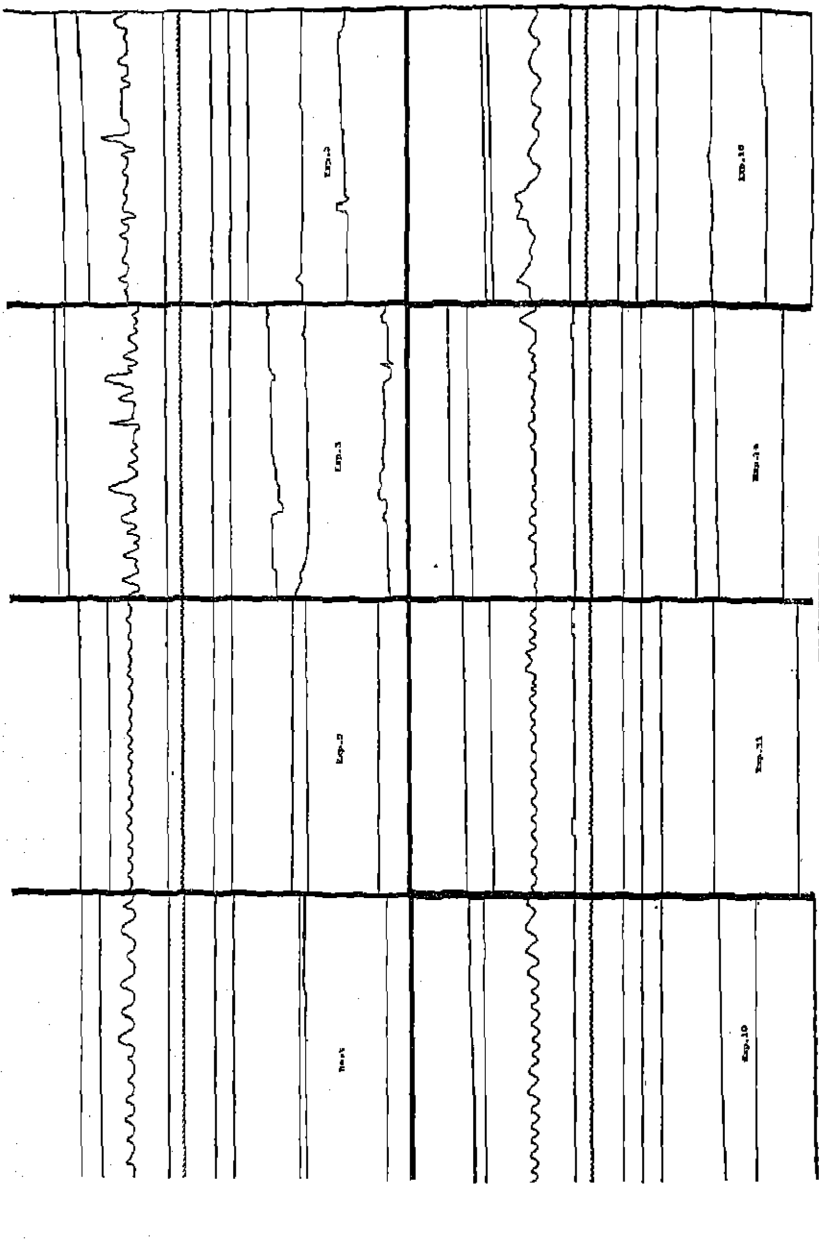

FIGURE 3B

Samples of sections of polygraph records obtained in various experimental periods appear in Figure 3 B.

As described above, the 1-minute samples from the records were selected systematically so as to give an unbiased and random sampling. In the rest records three samples were taken at regular points in the record —one 12 inches from the beginning, another 24 inches from the end of the first sample, and the third 12 inches from the end of the record. In rest periods of 1-hour duration, six samplings were made. Thus the samplings from all the records were taken at the same relative position within the record, so that data obtained for all subjects were taken from the same position in the corresponding record. The saliva samples, of course, were taken throughout the record, rather than within these 1-minute limits, and were treated as observations occurring at their appropriate position.

In all of the experimental records, polygraph samples were taken at the beginning, i.e., before the presentation of any stimulus, and at the end, i.e., after all stimuli had been presented. In Experiment 2, a sample was taken 10 inches before the stimulus signal for begining to read, another with the end of the sample superimposed on the point corresponding to the end of the story, and the last, 12 inches after the end of the story. Those taken from records obtained in Experiment 3 were: one 6 inches before presentation of first stimulus, two during the time that the snake was in the room, and one 12 inches after the presentation of the last stimulus. Quarter-minute samples were taken at the firing of the gun and at the sounding of the Klaxon.

In Experiment 10, one sample was measured immediately preceding the showing of the film; the second, 12 inches from the start of the film; the third, just before the end of the film; and the fourth, 6 inches beyond the end of the film. In Experiment 11, in addition to the two samples, one taken 6 inches before the beginning of the film and the other 6 inches past the end, three were taken during the time that the film was projected. Of these, one was taken for the part of the record made while the bathing beauties were being shown, the second taken during the dancing, and the third laid off so that the end of the sample coincided with the end of the moving picture.

In Experiment 14, in addition to the two samples taken at equivalent positions before and after the showing of the film, one sample was taken during the stage-coach hold-up and shooting scene, another during the cabaret scene, and another during the oriental dance before the sultan.

In addition to the usual samples taken before and after the projection of the film, those taken in Experiment 16 were one at the entrance of the actor into the dressing room, one covering two embraces, and another coincident with the end of the film. This sample included the scenes in which many prominent actors appeared. For a more complete description of the stimuli occurring within a given sample, cf. *supra* Section F.

H. THE SUBJECTS

All of the persons serving as subjects in this experiment were university students. Many were recruited from the experimenter's classes in elementary psychology, others were friends or acquaintances of these above-mentioned individuals, some were recruited from other classes in psychology, and still others were groups of fraternity initiates. Eighty-eight individuals served as subjects, in addition to 15 fraternity initiates, but since the results presented in this study were compiled from records obtained from 30 individuals, only these will be discussed.

Data obtained in the personal history blanks and from other sources will be briefly outlined. Fourteen of the group were males, 16 females. All reported for experimental sittings during the winter and spring quarters of the year 1929-1930, and 6 of them came also in the autumn quarter. (These latter gave approximately 3 hours per week for 38 weeks. This offering of time on the part of undergraduates was most sincerely appreciated.) Average age was 19.4 years, with range from 18 to 25. Academic maturity varied from first-quarter freshmen through graduates in their eighth year. Fourteen were in the second year. Eleven were employed in addition to their work in college. Times of arising, with special reference to the regularity or irregularity, were noted, as was the most frequent social activity. Any "most frequent" activity, however, loses significance in its influence since it was listed from the standpoint of occurring most frequently. For instance, a person attended two dances per week, two bridge parties, a reception, and three movies, so that the most frequent was, of course, the motion picture. Then in the case of another individual, social activities were minimal, with one dance per month, one club meeting, and two moving pictures—so the movie was again most frequent. Literary preferences varied widely, as did hobbies. Athletics engaged in concurrently with the experimental sittings were noted, mainly to ascertain activity engaged in preceding an experimental period. The contributory influence of such activity upon blood pressure, breathing, or salivary pH might be considerable. An increased heart rate, for instance, might be due to strenuous activity, rather than to fear. The number of meals per day with estimates of amounts of foods were noted so that the influence of digestive functions and preceding meal time might be considered, especially as affecting salivary pH. If the individual smoked, 20 minutes or more elapsed between smoking and the first saliva sample. Average number of hours of sleep per night, and number of nights per month on which retiring was later than 1:00 A.M. were recorded. University physical examination grades were obtained. (The only defect was a slight heart murmur in one subject.) Additional medical data were noted as they were presented by current physical exams, etc., and these will be referred to as occasion arises.

III

RESULTS

A. TREATMENT OF DATA

Job sheets, filled in from readings of polygraph records, constituted the raw data. Transmuted scores for variability in breathing and in blood pressure were used in computing standard deviations. Three line nomographs were constructed to facilitate the computation of standard deviations. Data from these job sheets were transferred to "difference sheets." This term is pertinent because the results were analyzed in every case from the standpoint of whether there were significant differences between reactions of various kinds, e.g., the difference between breathing rate during the presentation of a fear stimulus and breathing rate during rest, etc. All job sheets covering two rest periods, Experiments 2, 3, 10, 14, and 16, were selected for each subject. These job sheets included three sections from each of the rest records, and three for Experiment 2, six for Experiment 3, and four each for Experiments 10, 11,14, and 16. Samplings of records in the rest records were those of 1-minute duration measured at points 5 minutes after the beginning of the record, 3 minutes before the end of the record, and one at a position midway between these latter two. The job sheets for polygraph samples in Experiment 3 were as follows: a 1-minute sample at least 5 minutes after the beginning of the record and before the presentation of any stimulus; a quarter-minute sample at the time of the first gun shot; a complete sample (i.e., 1 minute) upon the entrance of the snake; a complete sample including the snake's "escape"; and quarter-minute samples at the sound of the Klaxon, at the flash, and at the second gun shot. Complete record samples were taken before, during, and after the short story was read in Experiment 2. Polygraph samplings in the experiments in which motion pictures were used (Numbers 10, 11, 14, and 16) were taken in the following manner: one before the projection, and three during projection. Scenes included in these samples will be referred to below when results from these data are discussed. Samples were taken in all records at the same relative position and at the same times in the experimental sittings so that direct comparisons validly could be made. Thus, physiological reactions to the same stimuli or stimulus situations could be compared for each subject.

Since data obtained in the difference sheets for all rest periods were approximately the same, just one will be discussed here as typical. The difference sheet for the third rest period in the series for each subject was selected. Data obtained when the control movie was shown (Experiment 10) were not significantly different from those obtained in normal rest. This was noted in the difference sheets where the scores in actual variables, i.e., frequencies, standard deviations, etc., as well as difference scores were about the same for each subject in both series. Likewise the difference sheets for Experiments 11 and 14 were quite similar to those for Experiment 16. Consequently, it seemed reasonable from the standpoint of general results to limit the discussion to Experiment 16 as typical of the series with emotional moving pictures as stimuli. So our discussion will be limited to the difference sheets for rest and Experiments 2, 3, and 16.

Differences between successive scores in each record were obtained, e.g., algebraic difference between rate of breathing in record sample 2 and sample 1, sample 3 and sample 2, sample 3 and sample 1, etc. Differences in the analysis of respiration were obtained for frequency scores, distance from maximum peak to minimum trough, number of atypical breaths, I/E ratios, and standard deviations. Differences in blood-pressure scores were: between maximum rise and maximum drop, durations of rise, durations of drop, number of sharp peaks, heart rate, and standard deviations. For the involuntary movements, differences in longitudinal frequencies, lateral frequencies, time of longitudinal movement, time of lateral movement, longitudinal maximum single excursions, lateral maximum single excursions, differences in longitudinal movements between maximal excursions in opposite directions, and differences in lateral movements between maximal excursions in opposite directions were obtained.

Differences in pH between successive saliva samples were listed in groups as pre-experimental, experimental, and post-experimental.

General trends characterizing the average subject were indicated by algebraic and arithmetic means of the differences for all subjects. Differences were averaged for all subjects in order to obscure individual trends. It was desired to obtain general trends, characteristic of the average subject. The particular differences are differences in some specific factor. The only actual values for individual subjects are those of pH, and these are not averaged because the direction of change as noted in this experiment is opposite to the change as noted in previous investigations. Significance of means was determined by the technique suggested by Fisher (28, pp. 104 ff.).[9] Means were tested as differing significantly from zero by the following formulae:

$$\frac{s^2}{n'} = \frac{1}{n'(n'-1)} S(x-\bar{x})^2$$

$$t = \frac{\bar{x}\sqrt{n'}}{s}, \qquad n = n'-1$$

From a table of t for values of n the probability of t falling outside the range of 1t is obtained. Values of p were halved (28, p. 105), since chances of exceeding the values of t were in terms of direction (positive for negative means, negative for positive means).[10]

The values of t and p for the means of difference scores obtained from various differences are presented in the following tables—Table 1 for rest records, Table 2 for records from Experiment 2, Table 3 for records from Experiment 3, and Table 4 for Experiment 16. The column headings indicate the differences treated: F_2—F_1 under *Breathing* is the difference in breathing rate between sample 2 and sample 1; $D.R._4$—$D.R._1$ under *Blood Pressure* is the difference between the duration of the rise in blood pressure in sample 4 and the duration of the rise in sample 1, etc. For example, in Table 2 for the rate of breathing, the second sample (F_2) minus the initial rest sample (F_1) gives an algebraic difference (in terms of t) of .902.

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[9] Sections on "The significance of the mean of a unique sample" and "Significance of the mean of a small sample."

[10] Probability of .01 or less is considered significant. In gross score terms, probability of .01 is equal to critical ratio of 2.3263, or p of .01 is equal to ratio of difference to probable error of difference of 3.4.

Differences in pH between successive saliva samples taken in various experimental periods are given in Tables 5, 6, 7, and 8.

B. ANALYSIS OF THE DATA

1. *Normal Rest Records.* In normal rest periods, we find significant variability between differences in various physiological reactions as obtained in different samples. The significant differences are in terms of variability as such, disregarding the direction of the difference. This is shown in Table 1 by the preponderance of significance in terms of very small probabilities when the arithmetic mean is considered. On the contrary, when the algebraic mean is used, we find the values of p rather large, at least greater than .01, so that the direction of the difference is not significant. It is to be recalled that small probability in our sense indicates high significance. It was noted from the difference sheet for rest records that there were marked differences, but these were very often in both directions, so that the algebraic sum was very small and

TABLE 1
REST RECORDS

BREATHING

	F_2—F_1		F_3—F_2		F_3—F_1		D_2—D_1		D_3—D_2		D_3—D_1	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	.902	.20	1.246	.15	1.100	.15	1.029	.15	1.511	.10	.150	.45
Arithmetic	5.693	*	5.080	*	5.059	*	4.331	*	4.347	*	4.918	*
	A_2—A_1		A_3—A_2		A_3—A_1		I/E_2—I/E_1		I/E_3—I/E_2		I/E_3—I/E_1	
Algebraic	.339	.38	.804	.21	.104	.46	2.320	.02	.557	.28	.557	.29
Arithmetic	6.113	*	5.306	*	5.220	*	3.229	*	.842	.22	6.686	*
Algebraic	1.081	.15	2.117	.02	.277	.39						
Arithmetic	4.049	*	4.057	*	4.269	*						

*NOTE: An asterisk (*) in the probability, p, column of this and the following tables indicates a probability (p) of less than .005.

BLOOD PRESSURE AND HEART RATE

	D_2—D_1		D_3—D_2		D_3—D_1		H.R.$_2$—H.R.$_1$		H.R.$_3$—H.R.$_2$		H.R.$_3$—H.R.$_1$	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	.237	.42	.614	.27	.456	.33	2.183	.02	1.594	.06	.849	.21
Arithmetic	2.374	.02	2.492	.01	2.746	.01	4.987	*	5.174	*	4.438	*
							D.R.$_2$—D.R.$_1$		D.R.$_3$—D.R.$_2$		D.R.$_3$—D.R.$_1$	
Algebraic	.115	.47	.533	.30	1.123	.13	1.178	.14	.938	.18	.450	.34
Arithmetic	2.901	*	2.579	.01	2.495	.01	1.894	.04	2.205	.02	2.010	.03

TABLE 1 (*continued*)

INVOLUNTARY MOVEMENTS

	LoF—LoF		LoF—LoF		LoF—LoF		LaF—LaF		LaF—LaF		LaF—LaF	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	.320	.37	.220	.42	.150	.41	1.210	.13	.030	.50	.880	.19
Arithmetic	2.812	*	3.100	*	2.470	.01	4.230	*	3.830	*	3.650	*

HYDROGEN ION CONCENTRATION OF SALIVA

	1st D		2nd D		3rd D	
	t	*p*	t	*p*	*t*	*p*
Algebraic	5.510	*	5.813	*	3.478	*
Arithmetic	10.310	*	5.273	*	5.254	*

TABLE 2

EXPERIMENT 2

BREATHING

	F_2—F_1		F_3—F_2		F_3—F_1		D_2—D_1		D_3—D_2		D_3—D_1	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	4.500	*	2.895	*	1.723	.04	1.456	.09	1.010	.16	.590	.30
Arithmetic	6.102	*	5.319	*	7.142	*	5.471	*	5.122	*	5.724	*
	A_2—A_1		A_3—A_2		A_3—A_1		I/E_2—I/E_1		I/E_3—I/E_2		I/E_3—I/E_1	
Algebraic	1.504	.07	2.645	.01	.871	.20	.122	.46	.155	.44	.119	.47
Arithmetic	5.951	*	7.916	*	7.128	*	VL	*	.372	.36	.611	.27
Algebraic	—1.614	.06	.848	.21	— .165	.44						
Arithmetic	6.162	*	4.269	*	5.485	*						

EXPERIMENT 2

BLOOD PRESSURE AND HEART RATE

	D_2—D_1		D_3—D_2		D_3—D_1		$H.R._2$—$H.R._1$		$H.R._3$—$H.R._2$		$H.R._3$—$H.R._1$	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	.226	.42	1.649	.05	.997	.13	2.289	.01	1.127	.13	.887	.19
Arithmetic	4.831	*	6.701	*	4.518	*	4.602	*	5.357	*	6.664	*
Algebraic	VL	*	— .165	.44	— .877	.19						
Arithmetic	VL	*	5.560	*	VL	*						

EXPERIMENT 2

INVOLUNTARY MOVEMENTS

	LoF_2—LoF_1		LoF_3—LoF_2		LoF_3—LoF_1		LaF_2—LaF_1		LaF_3—LaF_2		LaF_3—LaF_1	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	.051	.50	.54	.50	0		.998	.17	.236	.42	.721	.23
Arithmetic	2.701	*	2.596	.01	3.407	*	4.340	*	5.077	*	4.736	*

TABLE 3

EXPERIMENT 3

BREATHING

	F_2—F_1		F_3—F_2		F_3—F_1		D_2—D_1		D_3—D_2		D_3—D_1	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	1.420	.07	3.043	*	3.961	*	3.469	*	2.747	*	4.989	*
Arithmetic	7.286	*	7.900		12.389	*	7.129	*	6.064	*	8.952	*
	D_4—D_1		D_5—D_1		D_6—D_1		A_2—A_1		A_3—A_2		A_3—A_1	
Algebraic	3.168	*	1.970	.03	3.069	*	5.099	*	2.610	.01	6.467	*
Arithmetic	7.842	*	6.789	*	6.003	*	6.835	*	7.062	*	8.588	*
	I/E_2—I/E_1		I/E_3—I/E_2		I/E_3—I/E_1							
Algebraic	.672	.24	1.605	.06	.855	.20	3.851	*	1.744	.04	3.684	*
Arithmetic	9.363	*	5.748	*	6.156	*	6.002	*	5.255	*	7.870	*

EXPERIMENT 3

BLOOD PRESSURE AND HEART RATE

	D_2—D_1		D_3—D_2		D_3—D_1		D_4—D_1		D_5—D_1		D_6—D_1	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	.269	.39	3.776	*	3.672	*	4.599	*	1.661	.05	6.116	*
Arithmetic	5.42	*	6.947	*	5.585	*	5.906	*	4.228	*	7.219	*

TABLE 3 (*continued*)

	D.R._2—D.R._1		D.R._3—D.R._2		D.R._3—D.R._1		D.R._4—D.R._1		D.R._5—D.R._1		D.R._6—D.R._1	
Algebraic	1.929	.03	2.270	.02	3.386	*	.977	.19	.848	.21	3.182	*
Arithmetic	4.043	*	2.402	.01	4.017	*	3.116	*	2.427	.01	3.378	*
	D.D._2—D.D._1		D.D._3—D.D._2		D.D._3—D.D._1		D.D._4—D.D._1		D.D._5—D.D._1		D.D._6—D.D._1	
Algebraic	2.672	*	2.000	.02	3.595	*	3.461	*	1.474	.09	1.926	.03
Arithmetic	2.672	*	3.074	*	3.595	*	3.681	*	2.640	*	2.861	*
	NoP_2—NoP_1		NoP_3—NoP_1		NoP_4—NoP_1		H.R._2—H.R._1		H.R._3—H.R._1		H.R._4—H.R._1	
Algebraic	3.481	*	7.100	*	5.576	*	2.806	*	.674	.26	2.188	.02
Arithmetic	3.881	*	7.665	*	5.576	*	5.494	*	4.762	*	7.347	*
Algebraic	2.112	.02	5.757	*	4.351	*						
Arithmetic	5.757	*	5.757	*	7.586	*						

EXPERIMENT 3
INVOLUNTARY MOVEMENTS

	LoF_2—LoF_1		LoF_3—LoF_1		LoF_6—LoF_1		LaF_2—LaF_1		LaF_3—LaF_1		LaF_6—LaF_1	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	5.174	*	8.249	*	2.392	.02	3.857	*	5.935	*	3.009	*
Arithmetic	5.855	*	8.449	*	3.540	*	3.857	*	5.935	*	4.733	*
	LoT_2—LoT_1		LoT_3—LoT_1		LaD_2—LaD_1		LaD_3—LaD_1					
Algebraic	2.667	*	2.475	.01	3.855	*	10.388	*				
Arithmetic	2.734	*	2.530	*	4.455	*	10.388	*				

TABLE 4

EXPERIMENT 16
BREATHING

	$F_2—F_1$		$F_3—F_2$		$F_3—F_1$		$F_4—F_1$		$D_2—D_1$		$D_3—D_2$	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	.748	.22	1.072	.15	.169	.44	2.519	.01	3.646	*	2.269	.02
Arithmetic	8.105	*	4.595	*	7.332	*	8.870	*	5.402	*	3.280	*
	$D_3—D_1$		$D_4—D_1$		$A_2—A_1$		$A_3—A_2$		$A_3—A_1$		$A_4—A_1$	
Algebraic	1.367	.09	2.896	*	1.487	.08	.259	.40	1.244	.12	4.390	*
Arithmetic	5.719	*	4.674	*	5.385	*	6.859	*	5.148	*	6.513	*
	$I/E_2—I/E_1$		$I/E_3—I/E_2$		$I/E_3—I/E_1$		$I/E_4—I/E_1$					
Algebraic	2.396	.02	1.091	.15	3.270	*	2.536	.01	.548	.30	1.426	.09
Arithmetic	5.997	*	4.926	*	7.066	*	5.565	*	5.949	*	3.963	*
Algebraic	1.206	.11	1.720	.04								
Arithmetic	5.103	*	5.677	*								

EXPERIMENT 16
BLOOD PRESSURE AND HEART RATE

	$D_2—D_1$		$D_3—D_2$		$D_3—D_1$		$D_4—D_1$		$D.R._2—D.R._1$		$D.R._3—D.R._2$	
	t	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*	*t*	*p*
Algebraic	4.328	*	2.664	*	5.453	*	2.780	*	1.560	.06	3.828	*
Arithmetic	5.740	*	4.715	*	5.453	*	4.615	*	2.226	.02	3.828	*
	$D.R._3—D.R._1$		$D.R._4—D.R._1$		$H.R._2—H.R._1$		$H.R._3—H.R._2$		$H.R._3—H.R._1$		$H.R._4—H.R._1$	
Algebraic	4.065	*	1.697	.05	1.229	.13	1.263	.13	.935	.16	.875	.20
Arithmetic	4.156	*	2.391	.01	6.600	*	3.854	*	6.444	*	4.293	*
Algebraic	7.964	*	2.250	.03	5.051	*	3.864	*				
Arithmetic	7.964	*	3.033	*	5.051	*	4.882	*				

TABLE 4 (*continued*)

EXPERIMENT 16

INVOLUNTARY MOVEMENTS

	LoF$_2$—LoF$_1$		LoF$_3$—LoF$_2$		LoF$_3$—LoF$_1$		LoF$_4$—LoF$_1$		LaF$_2$—LaF$_1$		LaF$_3$—LaF$_2$	
	t	p	t	p	t	p	t	p	t	p	t	p
Algebraic	.796	.22	1.082	.16	.375	.36	.490	.32	.366	.36	2.094	.02
Arithmetic	3.075	*	2.233	.02	3.366	*	4.561	*	5.060	*	4.854	*
	LaF$_3$—LaF$_1$		LaF$_4$—LaF$_1$		LoSE$_2$—LoSE$_1$		LoSE$_3$—LoSE$_2$		LoSE$_3$—LoSE$_1$		LoSE$_4$—LoSE$_1$	
Algebraic	2.111	.02	.809	.21	2.126	.02	1.630	.05	.551	.30	2.116	.02
Arithmetic	4.985	*	5.125	*	2.504	.01	1.826	.03	3.191	*	2.505	.01
	LaSE$_2$—LaSE$_1$		LaSE$_3$—LaSE$_2$		LaSE$_3$—LaSE$_1$		LaSe$_4$—LaSE$_1$		LoD$_2$—LoD$_1$		LoD$_3$—LoD$_2$	
Algebraic	.820	.21	.351	.37	.231	.42	2.626	*	.080	.50	.096	.50
Arithmetic	19.125	*	2.916	*	3.277	*	5.014	*	5.266	*	3.265	*
	LoD$_3$—LoD$_1$		LoD$_4$—LoD$_1$		LaD$_2$—LaD$_1$		LaD$_3$—LaD$_2$		LaD$_3$—LaD$_1$		LaD$_4$—LaD$_1$	
Algebraic	.272	.39	2.550	.01	1.176	.14	.355	.37	.413	.33	2.726	*
Arithmetic	4.885	*	4.534	*	4.321	*	2.930	*	4.146	*	4.697	*

TABLE 5

REST

DIFFERENCES IN pH BETWEEN SUCCESSIVE SALIVA SAMPLES

Subject	1st D	2nd D	3rd D	4th D	5th D	6th D	7th D	8th D
A	.21	—.61	.13	.10	—.51	—.02	.00	.05
B	—.27	—.41	.26	.31	—.20	.12	.10	.02
C	.10	—.51	—.27	—.30	.00	.10	.42	.27
D	—.41	—.27	.31	.26	—.10	.00	.00	.37
E	1.73	—.73	.73	.61	—.82	—.11	.37	.20
F	.00	.10	.10	.15	—.20	.31	—.16	.00
G	.12	.26	—.41	—.25	.18	.31	.56	—.27
H	.06	.07	.00	.00	.10	—.27	—.31	.10
I	.40	—.39	—.51	—.27	.31	.40	—.10	.27
J	.79	—.25	.43	.33	—.10	.15	.23	.00
K	.77	—.91	.64	.20	—.88	.14	.09	.64
L	.00	.10	—.40	—.32	.27	—.10	.00	.00
M	.09	.00	.10	—.25	.00	.00	.31	.10
N	—.18	.02	.52	—.97	—.06	—.13	.60	—.40
O	—.10	.20	.00	.20	.13	.20	.14	.21
P	.37	—.75	—.61	1.33	—.78	.60	.41	.15
Q	—.02	.01	—.43	.25	.16	.04	.05	—.07
R	.05	.17	.10	—.10	—.20	.10	.00	.14
S	.46	—.50	—.10	.20	—.10	—.31	—.12	—.10
T	—.37	—.36	—.10	.00	.00	.10	.32	.10
U	—.60	1.00	—.47	—.32	—.16	.40	—.16	—.17
V	—.26	—1.10	.71	.86	.72	—.61	—.42	.27
W	—.12	.16	.00	.00	.20	.00	.40	—.36
X	—.56	—.41	1.12	—1.20	.40	.61	—.07	—.82
Y	—.60	—.27	.67	.82	—.97	—.26	.82	.27
Z	—.15	.31	.26	—1.00	—.02	.71	.90	.90
AA	—.15	.22	—1.04	1.03	—.10	.30	—1.19	.10
BB	—.60	—.26	—.82	.97	.36	—.10	—.10	.16
CC	—.26	—.37	.47	.86	.21	—.31	.27	—.02
DD	.54	—.54	.26	.00	.57	—.70	1.30	—.36

TABLE 6

EXPERIMENT 2

DIFFERENCES IN pH BETWEEN SUCCESSIVE SALIVA SAMPLES

Subject	Pre-experimental				Post-experimental			
	1st D	2nd D	3rd D	4th D	1st D	2nd D	3rd D	4th D
A	.20	.30	.10	—.10	.61	.10	.00	.10
B	.10	.16	—.15	.10	.40	.20	.10	.16
C	.20	.10	.81	.20	.20	.30	.41	.51
D	—.10	.28	.31	.26	—.86	.10	.20	.10
E	.11	—.61	.38	—.21	—.41	—.61	—.27	—.28
F	—.16	—.20	.16	.18	1.01	.68	1.02	—.61
G	.21	.36	.18	.10	.26	—.02	—.61	—.50
H	—.20	.00	.00	.10	—.77	1.11	—.10	—.08
I	—.30	—.20	—.10	.00	1.00	.86	.61	.10
J	—.20	.30	.40	.00	1.11	—.16	—.21	.05
K	—.32	—.27	—.41	.10	.07	—.20	.12	.30
L	.00	.21	.61	.20	.82	.21	—.61	.21
M	.20	—.10	.40	.10	.08	.10	.20	.30
N	.61	—.20	—.27	.16	.10	.40	.31	.01
O	—.44	.31	.00	.26	1.00	.61	—.10	.08
P	.19	—.18	—.46	.21	.10	.18	.20	—.11
Q	.00	.18	.16	.10	1.02	—.10	.68	.27
R	.20	.40	—.30	—.10	—.10	.40	.31	.26
S	—.44	.31	.00	.26	—.27	.00	.00	.41
T	.20	—.30	.40	.17	1.21	.02	.10	.16
U	.21	.20	.10	.16	.28	—.06	—.18	—.61
V	.60	.20	.00	.36	1.00	—.03	—.07	—.21
W	.61	.21	—.10	.16	—.86	—.10	—.10	—.17
X	.21	.12	.12	.10	—.38	.52	.41	.00
Y	.81	.12	.14	.16	—.86	—.40	.00	.36
Z	.00	.41	.10	—.20	—.71	—.10	.31	.00
AA	.40	.20	.20	—.08	1.02	.10	.10	—.48
BB	.61	.80	.61	.47	.87	.10	.27	—.36
CC	—.37	.21	.65	—.06	.60	.10	.61	—.27
DD	.41	—.16	.21	—.10	.30	.61	—.31	.00

TABLE 7

EXPERIMENT 3

DIFFERENCES IN pH BETWEEN SUCCESSIVE SALIVA SAMPLES

	Pre-experimental				Experimental				Post-experimental			
Subject	1st D	2nd D	3rd D	4th D	1st D	2nd D	3rd D	4th D	1st D	2nd D	3rd D	4th D
A	.21	.32	—.51	—.61	— .86	—1.71	— .80	.72	.31	.27	.16	.47
B	—.20	.16	.36	.41	— .26	—1.01	.82	— .49	.61	—.10	.71	.31
C	.10	.10	—.51	—.37	—1.61	.10	— .86	.11	.06	.21	.32	.08
D	—.14	—.10	.02	—.12	.33	.11	.13	—1.02	.10	.30	.61	.21
E	.18	.26	.10	.12	.21	— .17	—1.18	— .56	.37	.10	.08	—.06
F	.31	.10	.15	.21	— .86	— .91	— .27	— .38	.41	.32	.78	.82
G	.10	.12	.11	.61	—1.31	— .26	.86	— .37	1.10	.00	.10	.12
H	—.50	—.40	.37	.20	— .42	.21	— .96	— .61	1.00	.10	.20	.00
I	.10	.12	.00	.25	—1.06	— .27	— .30	— .18	.41	1.17	—.10	.61
J	—.01	.06	—.05	.04	—1.01	1.17	.03	.38	—1.06	—.01	.10	.46
K	1.02	.20	.10	.00	— .85	.40	.66	— .79	1.00	.20	.31	.10
L	.25	.46	.21	.12	— .71	— .86	.66	— .79	.98	.20	.31	.10
M	.03	.05	.10	—.02	— .10	.21	— .43	— .38	.21	.21	.26	.46
N	.00	.10	.21	.27	— .86	.29	— .21	—1.01	1.16	.27	.61	—.10
O	—.10	.21	.31	—.10	.32	.27	— .50	— .68	.86	—.10	.21	.01
P	—.18	.08	.10	.20	.52	— .60	— .82	— .11	1.07	—.30	—.41	.58
Q	.16	.00	.27	.26	—1.07	— .62	— .01	— .06	.87	.31	1.06	—.10
R	.03	—.04	—.10	.08	.25	.34	.70	.60	.68	—.70	—.41	.21
S	.15	.02	.10	.00	— .03	.30	.06	— .79	.21	.10	.05	.10
T	—.21	.00	.38	.00	—1.00	— .41	.08	— .21	.60	—.10	.27	.48
U	.08	.12	—.05	.00	— .10	.02	— .60	— .40	.78	—.20	.10	.00
V	.86	1.00	.41	.36	—1.06	— .18	— .16	— .27	.55	.40	.68	.90
W	—.05	.00	.00	.00	.60	— .65	.15	.30	.91	.00	.00	.15
X	.61	.81	—.72	.86	.61	.72	.86	—1.17	— .02	—.72	.86	.41
Y	—.05	.10	.02	.10	.32	— .60	.68	— .20	1.08	—.05	.20	.05
Z	—.51	.71	—.72	.86	—1.17	— .68	— .17	— .16	.71	.60	.81	.41
AA	—.82	1.03	.41	.20	—1.21	.40	— .86	— .17	.91	.01	.75	.68
BB	.30	.20	—.10	—.10	— .40	— .68	— .80	— .26	.10	.20	—.10	
CC	.69	.87	.08	.05	— .86	1.01	.86	.40	.91	.71	—.21	—.45
DD	.29	.10	.17	.02	.71	— .86	— .40	— .20	.20	.86	1.07	.21

TABLE 8

EXPERIMENT 16

DIFFERENCES IN pH BETWEEN SUCCESSIVE SALIVA SAMPLES

Subject	Pre-experimental 1st D	 2nd D	 3rd D	 4th D	Post-experimental 1st D	 2nd D	 3rd D	 4th D
A	.00	.10	.20	—.10	—1.00	— .36	.20	.41
B	.61	— .41	.37	—.81	.86	.20	.37	.26
C	—.41	.68	—.10	.86	—1.16	— .20	.37	.41
D	—.71	.21	—.38	.41	— .20	.86	.41	—.10
E	—.11	.10	—.08	.10	— .08	.55	—1.20	.70
F	—.10	.20	.18	.17	.41	.21	.31	—.10
G	.81	— .41	.61	—.20	1.02	.41	— .20	.31
H	.00	— .10	—.12	.21	—1.15	— .42	.86	.66
I	.00	.00	—.03	—.16	.10	.26	.11	.12
J	.71	.61	.45	.06	1.10	.41	— .71	.00
K	.13	.10	—.21	.10	.00	— .16	.37	—.50
L	.16	.26	.31	—.27	—1.06	.00	.45	.31
M	.00	.10	.86	.41	—1.05	— .17	.86	.61
N	.16	.61	.00	.46	—1.12	— .40	.10	1.05
O	.00	.10	.10	.10	1.11	.40	.00	—.61
P	—.08	— .16	.35	.10	—1.21	— .06	— .31	1.16
Q	—.06	.26	—.31	.10	—1.16	.01	— .21	.68
R	.10	.12	.21	.00	.19	.31	.64	.00
S	.70	—1.00	.60	.31	—1.00	.60	— .11	.84
T	.21	.17	—.06	—.11	.00	.27	.11	.21
U	.00	— .03	.10	.20	— .40	— .26	— .38	.38
V	1.00	.00	.41	.00	—1.05	— .41	— .01	.31
W	—.03	.71	—.20	.31	.00	.63	.86	.10
X	.00	— .08	.21	.46	.20	.86	.41	.31
Y	.61	.86	—.42	—.40	— .20	—1.01	— .40	.96
Z	.20	.21	.10	.00	.32	— .01	— .10	—.21
AA	.20	.31	.61	—.41	—1.00	— .18	— .16	.21
BB	.86	— .47	—.82	.98	—1.17	.71	.86	.19
CC	—.10	.61	.21	—.81	—1.21	.86	.91	.00
DD	.10	.00	.17	.38	.87	.81	— .10	—.12

the arithmetic sum very large. In general, there is consistency shown in the directions of differences by the same individual. That is, Subject A, for instance, shows a decrease in breathing rate when sample 2 is compared with sample 1. Similarly, there is a decrease in the frequency of lateral arm movements when sample 2 is compared with sample 1. Slightly over half of the individuals show this consistency, and the rest show no definite trend.

There is a very small difference in the means of the differences in breathing rate, in the differences between maximum minus minimum, and in the number of atypical breaths. There are marked individual differences and inconsistencies shown in comparison of atypical breaths. In general the differences are small, but some individuals show enormous differences. For instance, in the first rest sample, Subject V had 5 atypical breaths out of 13, in the second sample 15 atypical out of 17, and in the third 11 atypical out of 15. We may cite Subject CC, for instance, as being more nearly typical for the entire group. In the first sample this subject had 2 out of 21 breaths atypical; none in the second, in which breathing rate was 20; and 2 in the third, in which breathing rate was 20. It may be noted, as shown by the two cases cited above that inconsistencies are usually co-variant in a particular type of reaction, in this instance breathing. The first subject varies slightly more in respect to breathing rate than does the second, and considerably more in respect to number of atypical breaths.

Significance for all the differences listed on the difference sheets was not computed in instances in which 20 or more difference scores were 0, since such a small number of the population contributed to these differences. Probabilities for means of differences as shown by successive saliva samples were obtained for the rest data only, since the variability was as great or greater in the data from the other experimental periods.

It is interesting to note that we get only three significant differences in comparisons of standard deviations of breathing and blood pressure in rest records. The differences in I/E ratios are very small, and, when considering the significance of the means, just two are found significant.

On the basis of these results, some changes appear in the normal rest records just due to natural variability under these experimental conditions. This might be called a normal variability of the experimental situation. In subsequent experiments with emotional stimuli differences are to be looked for which are larger or more significant or more frequent than those differences occurring in the rest period. So these normal rest records, in addition to the initial rest periods in the emotional series, are included for comparison.

2. *Records from Experiment 2.* In the data from Experiment 2, there is a marked increase in the significance of the differences, especially in regard to the direction of the difference. We find rather consistent decreases in breathing rate, for instance, when the sample measured during the reading of the story is compared with that taken in the rest preceding the reading, the t being 4.500. The I/E ratio shows a significant

drop when that aspect of breathing is compared in the reading and rest samples. But when the two rest periods are compared, the I/E ratios are approximately the same. The standard deviations of breathing are substantially greater in rest than they are during reading. This was to be expected from comparing breathing curves on the polygraph records for Experiment 2. In general, the curves become more regular and of less amplitude for reading as compared with rest. In many records, the curve for each breath during reading was approximately the same as that for every other breath during reading. Inspiration time is decreased and expiration time is increased, as shown by the drop in I/E ratios mentioned above.

The differences between maximum rise and minimum drop in blood pressure (D_2—D_1, etc., in Table 2) as noted on the difference sheets are very small, with these small differences being in both directions. The duration of rises is also very short in every instance. In addition, none of the difference comparisons between duration of rise are significant. The same is true for the duration of drops. Out of the three samples for the 30 subjects, only six sharp peaks may be noted in the blood-pressure curves. There is also only a slight change in heart rate. The significance of this variability in heart rate is quite impressive, but it should be pointed out that the actual differences as shown on the difference sheet are very small, being differences of —1 or —2, or 0. It is interesting, though, that 13 differences were negative, 2 positive, and 15 were 0. Thus almost half of the individuals showed a slight significant decrease in heart rate.

Differences in frequency of arm movement are striking. Considerably more movement is shown during reading than during rest. The differences show no consistency in direction, but the variability is greatly increased, with variability in lateral movement approximately twice as large as variability in longitudinal movement. The times of movement, single excursions, maximum minus minimum differences, and other aspects of involuntary movement are so highly variable that a composite treatment of these aspects for the entire group would be totally meaningless. Enormous individual differences in these aspects are quite apparent in the difference sheets.

The differences in pH between successive saliva samples are shown in Table 6. The first difference listed as post-experimental is the difference between the first sample taken immediately after the subject finished reading the story and the sample taken just before he started to read the story. Since the total reading time was small, this difference is comparable in terms of elapsed time with any other difference in the table. In general, this difference is greater than other differences, but there are 21 increases in salivary pH and 9 decreases.

We thus find the outstanding differences in Experiment 2 in terms of decrease in breathing rate during reading with an accompanying drop in I/E ratios; standard deviations are also less during reading than during rest. Differences in blood pressure are very small and no consistency in direction is noted. Very consistent small differences in heart rate are noted, with about half of the subjects showing a slight decrease in heart rate during reading. Differences in frequency of arm movement show a decided increase during reading. Lateral movements occur about twice as frequently as do longitudinal movements. Twenty-one of the 30 subjects show an increase in pH of saliva after reading the story. These increases range from .08 pH to 1.21 pH.

3. *Records from Experiment 3.* Data from Experiment 3 analyzed for significance of differences are presented in Table 3. As previously noted, polygraph sample 1 was taken during rest preceding the presentation of any stimulus; sample 2 upon the entrance of the snake; sample 3 covering the snake's "escape"; sample 4, a small sample at the first gun shot (preceding snake's entrance); 5, a sample of the same size at the sound of the Klaxon; and 6, a small sample at the second gun shot.

In regard to breathing rate, about half of the subjects show a marked decrease in 2—1 (sample 2 minus sample 1) comparisons, and the other half an equally outstanding increase. It was thought at first that there might be some consistency in increase or decrease in breathing rate due to "gasps of surprise," etc., but none was apparent in this study. The experimenter had concluded from observing polygraph records that individuals who took more breaths per minute than the average during rest would show marked increases in breathing rate during the snake's escape, for instance, and those who took slightly fewer breaths than the average would show a decrease. Such was not the case. Subject C, whose breathing rate during rest was 22, shows an increase of 5 breaths per minute during the snake's escape which was sample 3, and Subject T, whose breathing rate was 23 during rest, shows a decrease of 7 breaths per minute in sample 3. Subjects J and DD, whose rate during rest was 15 breaths per minute, show an increase of 8 and a decrease of 4, respectively.

Comparisons of differences between maximum and minimum values in the breathing curve are striking. A marked increase in the magnitude of these differences is shown in D_2—D_1 comparisons. For 22 individuals there is a very large increase, for 1 a correspondingly large decrease, and for 7 a correspondingly small decrease. A greater increase is shown in the samples covering the sound of the Klaxon than in the case of either gun shot, with the second gun shot causing a greater increase than the first.

The number of atypical breaths for samples 2 and 3 is considerably larger than that for sample 1, with sample 2 having the largest number.

There is a marked consistent increase in I/E ratios in 2—1 comparisons with an increase slightly less in magnitude in 3—2 comparisons; 3—1 comparisons also showed an increase. Standard deviations in samples 2 and 3 are considerably larger than those in sample 1, with those in sample 3 consistently less than those in sample 2.

In blood-pressure difference comparisons an increase over those in sample 1 is shown by all other samples of the polygraph record. Durations of rise are consistently increased, as are durations of drop. Durations of rise are much more frequent than durations of drop. Difference scores for D.R.$_2$—D.R.$_1$ are markedly greater than those for any other D.R. comparisons, since they occur in a large magnitude in every instance. The D.R.$_3$—D.R.$_2$ values are fewer but also large, and serve to indicate that the rises in blood pressure are sustained longer during the snake's escape than in any other sample. The drops are less frequent, but those which do occur are maintained longer than the rises. The number of sharp peaks in the blood-pressure curve is largest in sample 3. Both the algebraic and arithmetic means for the difference columns in number-of-sharp-peaks comparisons are highly significant, thus giving great significance to the increase in number of sharp peaks. There is an increase in heart rate in sample 2 as compared with sample 1 in about 8 cases, a decrease in 8, and no difference in 14. The variability in blood pressure steadily increased through samples 2 and 3. It is also significant that p is very low for the standard deviation of each comparison, being greater than .005 in only one algebraic comparison (Table 3).

There is a marked increase in frequency of movement both longitudinally and laterally in 2 over 1, and an equally marked increase of 3 over 2. The frequency of lateral movements is greater than the frequency of longitudinal movements. Total times of lateral and longitudinal movement become significant here, and these differences occur for a large proportion of the total population. Thus we find all means stable and marked increases noted.

Differences in pH are shown in Table 7. The outstanding feature is the comparatively large decrease in salivary pH with the presentation of the snake, with a subsequent rise or "return to normal" in the post-experimental period.

The results from Experiment 3 may be briefly summarized as follows: Two trends in differences between breathing rates are noted, namely, that half of the subjects show a marked increase in breathing rate when fear and shock stimuli are presented, and half of the subjects show the opposite—a marked decrease in breathing rate when the same stimuli are presented. The traditional "gasps of surprise" were wholly absent. Differences between maximum and minimum points on the breathing curve are greater in the samples in which fear stimuli were used. Number of atypical breaths increases—with a greater increase of atypical breaths in sample 3 (snake's escape) relative to sample 2 (snake entering the experimental room). The I/E ratios likewise increase—those in sample 2 being slightly greater than those in sample 3. Standard deviations of breathing for samples 2 and 3 are considerably greater than those for sample 1, with those for 2 somewhat greater than those for sample 3.

Most all aspects of blood pressure increase with the presentation of fear stimuli. More sustained rises are noted than sustained drops. The drops, though occurring less frequently, are sustained the longer. Variability as indicated by standard deviation is increased when fear stimuli are presented. In general, slight increases in heart rate are as frequent as slight decreases, but both increase and decrease are less frequent than the category of "no difference."

The frequency of arm movement is increased. Lateral frequency is the greater. This is the first experiment in which total times of movement becomes significant. In the data for rest and for Experiment 2 total times of movement were not significant. Here we find total time difference scores quite large, and contributed to by a very large proportion of the population.

Consistent and comparatively large drops are noted in salivary pH with the presentation of fear stimuli, the largest decreases occurring when the snake is presented. In the post-experimental period, salivary pH increases gradually.

It becomes evident that there is a rather typical physiological pattern with the extreme fear stimuli. All of the subjects are characterized by the co-variation of some reactions. Thus the typical picture in fear is as follows: extremely marked increase or decrease in breathing rate, with no gasps or chocs; apparent trends in normal breathing rate drop out; marked increase in amplitude of breathing; number of atypical breaths in a unit time very large; great increase in I/E ratios; rises in blood pressure frequent, lasting relatively long; drops less frequent than rises, but longer sustained; sharp and abrupt rises in blood pressure; decrease in salivary pH; no immediate pronounced changes in heart rate. Arm movements do not enter as part of a pattern because they lack consistency—they are characterized only by variability. Further aspects of quite definite patterns may be culled from Tables 9, 10, and 11.

TABLE 9

Aspects of Breathing

Stimulus	F. Comp. *M*	F. Comp. *t*	F. Comp. *p*	D. Comp. *M*	D. Comp. *t*	D. Comp. *p*	A. Comp *M*	A. Comp *t*	A. Comp *p*	I/E Comp. *M*	I/E Comp. *t*	I/E Comp. *p*	Comp. *M*	Comp. *t*	Comp. *p*
Rest	2.26	5.693	*	1.53	4.387	*	3.63	5.220	*	15.92	6.686	*	7.23	4.099	*
Reading	2.71	6.102	*	2.73	5.471	*	3.03	5.591	*	15.47	VL		8.65	6.162	*
1st gun shot				5.2	7.84	*									
Snake	4.1	7.286	*	5.6	7.13	*	6.4	6.84	*	2.8	9.36	*	12.4	6.00	*
Snake's escape	6.5	12.39	*	8.7	8.95	*	7.5	8.58	*	2.4	6.16	*	1.9	7.87	*
Klaxon				5.7	6.79	*									
2nd gun shot				5.6	6.0	*									
Disgust	3.03	8.11	*	4.13	5.40	*	2.47	5.39	*	18.9	5.0	*	6.10	5.95	*
Sex	2.57	7.33	*	4.23	5.72	*	2.63	5.15	*	19.1	7.0	*	8.99	5.10	*
Subtle Sex	3.43	8.87	*	2.63	4.67	*	3.33	6.51	*	14.9	5.57	*	8.04	5.68	

TABLE 10

ASPECTS OF BLOOD PRESSURE AND HEART RATE

	D. Comp.			D.R. Comp.			D.D.Comp			No. SP Comp.			H.R. Comp.			Comp.		
Stimulus	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*
Rest	2.86	2.746	*	3.50	2.205	.02	N			N			.80	5.174	*	4.09	2.495	*
Reading	2.07	4.831	*	N			N			N			.83	4.602	*	39.9	VL	
1st gun shot	6.9	5.91	*	9.8	3.12	*				1.3	5.58	*						
Snake	5.6	5.29	*	10.5	4.04	*	6.12	.67	*	1.4	3.88	*	1.7	5.49	*	.8	5.76	*
Snake's escape	6.9	5.58	*	20.6	4.02	*	12.7	3.89	*	3.8	7.67	*	3.0	7.35	*	10.9	7.59	*
Klaxon	4.4	4.23	*	8.2	2.43	.01	4.0	2.69	*									
2nd gun shot	9.4	7.22	*	12.7	3.38	*	N											
Disgust	3.99	5.74	*	2.6	2.22	.02	N			N			2.1	6.60	*	9.0	7.96	*
Sex	6.87	5.45	*	14.6	4.15	*	N			N			1.8	6.44	*	16.4	5.05	*
Subtle sex	3.30	4.62	*	2.3	2.39	.02	N			N			1.9	9.29	*	6.0	4.88	*

TABLE 11

ASPECTS OF INVOLUNTARY MOVEMENTS

	LoF Comp.			LaF Comp.			LoT Comp.			LaT Comp.			LoD Comp.			LaD Comp.		
Stimulus	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*	*M*	*t*	*p*
Rest	.86	3.100	*	2.16	4.234	*	N			N			N			N		
Reading	1.43	2.701	*	2.17	4.344	*	N			N			N			N		
1st gun shot																		
Snake	5.1	5.86	*	9.5	3.86	*	20.4	2.74	*							16.5	3.86	*
Snake's escape	14.2	8.45	*	40.1	5.94	*	23.0	2.53	*							37.5	10.4	*
Klaxon																		
2nd gun shot	2.3	3.54	*	4.6	4.73	*												
							La. SE Comp.			Lo.SE Comp.								
Disgust	1.13	3.07	*	2.36	5.06	*	2.93	19.1	*	.96	2.50	*	3.33	5.26	*	2.73	4.32	*
Sex	.69	3.36	*	1.59	4.98	*	2.03	3.27	*	1.49	3.19	*	7.45	4.88	*	3.66	4.41	*
Subtle sex	.93	4.56	*	2.29	5.12	*	1.67	5.01	*	.96	2.50	*	3.20	4.53	*	3.03	4.69	*

4. *Records from Experiment 16.* In Experiment 16, sample 1 of the polygraph record is again rest preceding the showing of films, sample 2 covers the scene in which a man is slapped after forcing his attention upon a woman, sample 3 includes scenes of an actor and a chorus girl in conversation, and two lingering embraces, and sample 4 covers several scenes in all of which prominent stars are featured, each scene offers a much less repulsive situation than that offered in the section covered by sample 3.

The *t*'s and *p*'s for the various comparisons appear in Table 4. Differences here are strikingly significant —many being significant in direction. Most of the blood-pressure difference comparisons are significant in direction. The number of significant differences in this respect compares most favorably with that of the same categories in Experiment 3.

In 2—1 comparisons for various aspects of breathing, breathing rate consistently increases in sample 2. The amplitude of breathing is considerably less, since most D_2—D_1 scores are negative—and we find this to be highly significant in terms of probability, *p* considerably less than .005. Atypical breaths increase in number, and there is a consistent and marked decrease in I/E ratios, and, strangely, a marked difference in variability, with about half of the individuals showing a larger standard deviation, and half a smaller standard deviation. This shows a rather uniform shift in breathing. Since all subjects have a smaller I/E ratio (than those in rest) those showing increased variability would necessarily have the same relation of inspiration time to expiration time as those showing a decreased variability. The latter type shows a regularity in breathing similar to that found in reading in Experiment 2.

There is a small increase of breathing rate in sample 3 over 2, and a large increase of 4 over 1, with 4—1 differences rather consistently larger in a positive direction than those of any other movie—rest comparison. If the stimuli in sample 4 were more effective than others, it could be said that reactions were due to a finer type of acting. The maximum-minimum comparisons for D_3—D_1 are consistently large in the negative direction, although the algebraic mean is not significant, and the D_4—D_1 scores are slightly smaller but all are negative. We note that the algebraic mean here is significant. Thus, in watching the more stimulating action in section 4, breathing rate is faster, but breathing is more uniform in amplitude and wave length. *Very strangely, there is a decrease in I/E* ratios in 3—1 comparisons, the mean of which is most significant (algebraic t=3.270), and a marked increase of I/E ratios in 4—1 comparisons, with an algebraic $t = p$ .01. This suggests that there are further shifts in breathing beyond those of amplitude and frequency. Variability is significantly greater in sample 3 than in 1 in terms of standard deviation, but one-fourth of the population showed small negative differences, and three-fourths a large positive difference, hence a grouping tends to destroy the trends actually shown by the original data.

In over 85% of the blood-pressure differences the direction is positive for the total population. There is consistent increase in all aspects of blood pressure, with 3—1 differences being larger in every case than other comparisons, and 4—1 differences smaller than other comparisons. The increase in heart rate is slight in 2—1, 3—1, and 4—1 difference comparisons, and is about equal in magnitude for each comparison. Standard deviations for these comparisons are slightly greater but more consistent—and it is interesting to note in Table 4 that all algebraic means are significant except one and it has a $p=.03$, while all of the arithmetic means are significant.

Involuntary movements in respect to longitudinal frequency are about the same in all samples. The first noticeably varying differences are in lateral frequency comparisons, these being consistently negative in small amounts in 2—1, 3—1, and 4—1 comparisons. Total times of longitudinal and lateral movement are negligible, since most of the difference scores as well as the original values (as plotted on difference sheets) are zero. Longitudinal single excursions are small, with all differences negative; difference scores appear for 11 of the total population. Lateral single excursions are comparatively larger, most differences negative, and difference scores appear for 22 individuals out of 30. Lateral movements have consistently shown greater differences than longitudinal movements in both Experiments 3 and 16. The differences in values for maximum excursion from preceding rest, noted as La.D. and Lo.D. scores, are most variable, so that any composite for the group is meaningless.

The differences in hydrogen ion concentration of the saliva samples are shown in Table 8. There is a rather consistent decrease in pH during the showing of the films, but it is to be remembered that here the time elapsing between the samples contributing to the first difference in the post-experimental group was the time required to project the film—about 10 minutes.

To summarize briefly: An increase in breathing rate is noted when a disgusting scene is shown. In a cruder type of sex stimulation, the breathing rate again increases—slightly more than the increase previously noted. The largest and most consistent increase in breathing rate is noted in the samples covering the scene in which more subtle and higher types of sex stimulation are presented. The I/E ratios drop during the disgusting scene (sample 2) and the cruder type of sex stimulation (lingering embraces, etc.—sample 3). During the scene in which more subtle and higher types of sex stimulation are presented (sample 4) the I/E ratios increase when compared with the I/E ratios during rest. In general, standard deviations of breathing increased.

Approximately 85% of the difference comparisons for various aspects of blood pressure increase in samples 2, 3, and 4, when compared with sample 1. The increases are greatest and most consistent in sample 3, e.g., scenes of lingering embraces, actors and chorus girls. Blood-pressure rises are more frequent and are sustained longer, blood-pressure drops are more frequent and are sustained longer, etc. Slight increases in heart rate about equal in magnitude are found in

2—1, 3—1, and 4—1 comparisons. Variability in blood pressure as indicated by standard deviations is greater in samples 2, 3, and 4 than in sample 1.

No change is noted in the frequency of longitudinal movements. A marked decrease occurs in the frequency of lateral movements. All aspects of lateral movement show greater variability than the aspects of longitudinal movement.

Rather consistent decrease in pH is noted after the projection of the film. The decreases noted in Experiment 16 are on the whole considerably less than those noted in Experiment 3.

Again rather definite physiological patterns for definite stimuli are presented. A very clear-cut difference is that in I/E ratios—a drop for the disgusting stimuli and crude sex stimuli, and an increase in I/E ratios for the higher types of sex stimuli. Here the concomitant variation is quite evident, as it was with the fear stimuli. Both the rate and amplitude of breathing characterize the film used as stimulus. Patterns are evident in Tables 9, 10, and 11.

IV

CONCLUSIONS

Perhaps the most striking aspect of the physiological reactions used as variables in this study is the great variability displayed. Variability increases in emotional situations. All of the polygraph records obtained during the presentation of emotional stimuli can be differentiated readily from records obtained in normal rest.

Variability as such differs in various emotional situations. A marked increase in variability was noted in situations in which intense fear stimuli were presented. Variability was somewhat less in the situations in which films depicting disgusting scenes were shown.

Some of the more clearly differential aspects of breathing in various situations are presented in Table 9. The means, *t*'s, and probabilities are shown for various types of differences. The column headings indicate the types of comparisons from which differences were obtained.

Variability in breathing rate is seen to be differential. The most striking differences in rate are found in intense fear situations. Subtler sex stimuli may be differentiated from a grosser type of sex stimulation in terms of breathing rate. With reference to variability in breathing rate during fear situations, about half the population showed a marked increase and the other half a marked decrease.

The differences between maximum and minimum points on the breathing curve were greater for the fear and shock stimuli than for the disgust and sex stimuli, but these latter differences were considerably greater than those in normal rest.

Inspiration-expiration ratios were found to increase in fear and shock, and to decrease in disgust and with grosser sex stimulation. The I/E ratios increase markedly, however, when more subtle sex stimulation is presented.

Breathing curves show considerable variability in amplitude in normal rest, as indicated by standard deviation values. These values increase, however, in emotional situations, with the greatest increases occurring with intense fear stimuli.

The outstanding differentia as shown by various aspects of blood pressure and heart rate are presented in Table 10. Consistent increases in number of rises, duration of rises, number of drops, and duration of drops were noted in the cases of intense fear stimuli. Sustained rises were more frequent than sustained drops, but the drops were longer in duration than the rises. Increases were noted with the disgust and sex stimuli, with the most frequent increases occurring when scenes depicting lingering embraces were shown. The amount of variability as indicated by standard deviation measures was shown with the fear stimuli. Changes in heart rate in all instances were very small. Slight increases and slight decreases were equally frequent in fear situations. Increases were more consistent in disgust and sex.

Outstanding characteristics of involuntary movements are shown in Table 11. No definite trend of direction of movement was noted—at least no two-category classification such as "approach and avoidance" could be made. Lateral movement in all instances was more frequent, more variable, and greater in magnitude than longitudinal movement. The main differentia for various emotional situations are primarily quantitative. It may be said that the greater individual differences were manifest in involuntary movements than in any other reactions.

Great variability was noted in pH of saliva. Consistent drops of rather large amounts were found to accompany the presentation of fear and shock stimuli. Consistent drops somewhat less in magnitude followed the showing of the film in Experiment 16.

Physiological patterns for definite stimuli were evident. We have given above a definite pattern for extreme fear, for instance. Significant co-variations do occur. Determining correlations with a view to weighting the different variables should prove illuminating.[11] There is some indication that a factor analysis would determine how many physiological factors are actually necessary to account for intercorrelations.

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[11] This phase of the problem is now being undertaken.

V

SUMMARY

A rather comprehensive survey of the literature on emotions reveals considerable experimental interest. Efforts at "measuring emotions" have been made by a large number of persons for a long period of time. An increase in this type of study was shown just before and during the World War, and a great many investigations have been carried out since that time.

We found that no study had recorded simultaneously varying physiological reactions, and hence undertook the present investigation. Stimuli socially classifiable as emotional were presented to a large number of adults under rather carefully controlled experimental conditions. Each subject served in several experimental periods. During the experimental periods, continuous records of blood pressure, respiration, and arm movement were made, and saliva samples were taken at intervals. The hydrogen ion concentration of these saliva samples was subsequently determined.

All recording was done in a polygraph-ink on paper. A pressure-reducing device enabled the experimenter to obtain continuous blood-pressure records without causing discomfort to the subject. By using hypodermic syringes to obtain samples of saliva, and small pyrex bottles to contain these samples and serve also as electrode vessels, contact of saliva with air was momentary.

Great variability was shown in the physiological reactions measured. Variability in breathing rate and amplitude was significant during normal rest, as was variability in frequency and extent of arm movements. Blood-pressure changes were less variable during rest but the hydrogen ion concentration of successive samples of saliva varied significantly under rest conditions.

Variability in these physiological reactions was increased in emotional situations. The greatest increase in variability occurred when intense fear stimuli were presented. All aspects of breathing increased with fear stimuli, whereas in disgust and with sex stimuli amplitude of breathing was diminished and rate increased. The traditionally noted "choc" or gasp in surprise was totally absent in our results.

Blood-pressure rises and drops were more frequent in fear. Rises occurred more often than drops in blood pressure, but the latter were longer in duration. Blood-pressure rises were more frequent and greater in magnitude when subtle sex stimuli were presented than when a cruder type of sex stimulus was used. The inspiration-expiration ratios decreased with fear stimuli; a decrease was also noted in disgust, and with cruder sex stimuli. These ratios increased when more subtle sex stimuli were presented.

In all types of emotional situations, arm movements in lateral directions were more frequent and of greater extent than arm movements in longitudinal directions. Both types of movement were greater in fear situations. When sex stimuli were presented, longitudinal movements were negligible, whereas lateral movements were quite significant.

Results of hydrogen ion determination of saliva samples were contrary to those noted in previous investigations. Decreases, consistent and comparatively large, occurred when fear stimuli were presented. With disgust and with sex stimuli, the decreases were consistent, but were smaller in magnitude than those observed in fear situations.

An extension of this type of investigation should prove fruitful. Great progress should be made in classifying emotional reactions and in describing emotional behavior. Establishing the amount of co-variation in various types of physiological reactions in emotional situations would enable one to give a complete analysis of emotional behavior.

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LA MESURE OBJECTIVE DES RÉACTIONS ÉMOTIVES

(Résumé)

Il existe un type de comportement ou catégorie de réactions qu'on a appelé émotion. L'homme ordinaire et l'homme de science ont montré un très vif intérêt pour les problèmes de l'émotion; on trouve un intérêt manifesté pour le problème de faire naître une émotion agréable chez un acheteur possible, de calmer l'agitation d'un malade névrosé, de découvrir la culpabilité ou l'innocence d'une personne soupçonnée, et pour grand nombre de ces problèmes qui exigent une connaissance du comportement émotif pour les résoudre. Par conséquent, on a fait bien des études du comportement émotif—la classification des émotions, l'observation subjective des états émotifs, l'observation des réactions collectives du corps dans l'émotion, des tests employant "papier et crayon" pour mesurer le rendement d'une personne dont les émotions ont été stimulées, et la notation plus exacte des changements physiologiques dans l'émotion. Dans cette étude il s'agit du dernier type.

Un résumé des écrits a montré grand nombre d'études où l'on a noté les changements physiologiques dans l'émotion, mais on n'a employé plusieurs variables simultanément dans aucune de ces études. Par conséquent, on a essayé dans cette étude de noter les changements de la respiration, de la pression sanguine, et des mouvements involontaires d'un bras, et d'obtenir des échantillons de salive mixte, dont l'on a déterminé la concentration des ions d'hydrogène. On a analysé de plusieurs façons les notations de chaque réaction.

On a pris des échantillons non choisis dans diverses notations pour chaque personne pour la mesure. On a analysé toutes les réactions en termes des différences, c'est-à-dire, les différences de la même réaction dans le repos normal et dans l'émotion. On a déterminé la signifiance des moyennes par une technique de probabilité.

Toutes les réactions physiologiques employées dans cette étude ont été très variables—même dans les conditions du repos. La variabilité est devenue plus grande d'une manière signifiante quand on a présenté des stimuli émotifs.

Pour les stimuli de grand'peur, on a noté des formes types de réponse. La vitesse de la respiration s'est beaucoup accrue pour la moitié des sujets, et l'autre moitié a montré une décroissance également claire. Les "soupirs de surprise" ordinairement notés ont été totalement absents. Un grand accroissement des proportions I/E s'est montré. Les accroissements de la pression sanguine ont été plus fréquents que les décroissances, mais celles-ci ont été soutenues plus longtemps. Le plus grand nombre de grands accroissements de la pression sanguine s'est montré quand un serpent vivant de plus de deux mètres de long rampait sur le plancher près de la chaise du sujet. Les petits accroissements du rythme cardique ont été aussi fréquents que les petites décroissances pendant la peur. On a noté des décroissances constantes du pH salivaire,—contraire aux études antérieures.

Les types plus subtils de stimulation ont été caractérisés par des changements de la forme de réaction. Les proportions I/E, par exemple, décroissent quand on présente des situations dégoûtantes, et s'accroissent quand on présente des stimuli esthétiques.

La variabilité est différentielle dans toutes les réactions. On a noté une forme complète, en termes de variabilité concomitante, pour les types de réaction émotive. Le stimulus a été facilement indiqué par la forme de l'enregistrement du polygraphe. Une extension de ce type d'investigation

désigné pour établir la quantité de co-variation dans les divers types de réactions physiologiques dans les situations émotives rendrait possible une analyse assez complète du comportement émotif.

GASKILL

DIE OBJEKTIVE MESSUNG DER GEÜHLSREAKTIONEN

(Referat)

Es gibt eine Reagierungsweise, oder eine Kategorie der Reaktionen, die "Gemütsbewegung" [emotion] genannt worden ist. Sowohl der Laie wie der Gelehrte hat für die Probleme der Gemütsbewegungen eine kolossal starke Interesse erwiesen. Man hat sich interessiert für die Aufgabe des Erzeugens einer angenehmen Gemütsbewegung bei einer Versuchsperson, der Beruhigung eines Nervenleidenden, der Entdeckung der Schuld oder Unschuld eines Verdächtigen, und für unzählige andere Aufgaben dieser Art, zu deren Bewältigung eine gewisse Vertrautheit im Bereich der Gefühlsreaktionen nötig ist. Es haben folglich zahlreiche Untersuchungen der Gefühlsreaktionen stattgefunden. Darunter finden sich z. B. Klassierungen der Gemütsbewegungen, subjektive Beobachtungen der Gefühlzustände [emotional states], Beobachtungen der grossen körperlichen Reaktionen bei Gemütsbewegungen, Prüfungen mit Bleistift und Papier ["pencil and paper" tests] zur Messung der Leistung einer affektiv gereizten Versuchsperson, und die genauere Notierung der physiologischen Veränderungen bei Gemütsbewegungen. In der gegenwärtigen Untersuchung hat man sich mit einer solchen Notierung beschäftigt.

Eine Literaturübersicht beweist, dass es eine ganze Menge Untersuchungen gibt, in denen physiologische Änderungen bei Gemütsbewegungen notiert worden sind. In keiner dieser Untersuchungen, aber, sind verschiedene Variablen gleichzeitig undersucht worden. Wir haben also versucht, Veränderungen der Atmung, des Blutdruckes, und der unwillkürlichen Bewegungen einen Armes zu notieren und regelmässig von Zeit zu Zeit Proben gemischten Speichels zu erhalten, dessen pH Konzentrierung [hydrogen ion concentration] dann bestimmt wurde. Die Notierungen über jede Reaktion wurden auf viele Weisen analysiert.

Ohne Vorurteil gewählte Exemplare [samples] aus verschiedenen Protokollen von jeder Versuchsperson wurden zu den Messungen verwendet. Alle Reaktionen wurden in Bezug auf Unterschiede—z. B. Unterschiede zwischen normaler Ruhe und Gemütsbewegung bei der selben Reaktion—analysiert. Die Bedeutung der Durchschnittszahlen wurde mit einem Verfahren zur Bestimmung der Wahrscheinlichkeit [probability technique] ermittelt.

Alle in dieser Untersuchung beobachteten physiologischen Reaktionen erwiesen sich als höchst veränderlich—auch im Ruhestande. Wurden affektive Reize [emotional stimuli] dargeboten, so steigerte sich die Variabilität bedeutend.

Bei den extremen Angstreizen wurden typische Reaktionsgestalten beobachtet. Die Atmungsschnelligkeit nahm bei einer Hälfte der Versuchspersonen bedeutend zu, und bei der anderen Hälft eben so stark ab. Die traditionell beobachteten, plötzlichen scharfen Einatmungen bei der Erstaunung ["gasps of surprise"] fehlten vollständig. Es fand eine starke Zunahme im Einatmungs-Ausatmungsverhältnis [inspiration-expiration ratio] statt. Erhöherungen des Blutdrucks fanden häufiger statt als

Erniedrigungen, aber letztere beharrten länger. Die grösste Zahl plötzlicher Erhöherungen fand man, wenn man eine, mehr als sechs Fuss lange, lebendige Schlange auf dem Fussboden in der Nähe des Stuhles der Versuchsperson umherkriechen liess. Bei der Angst zeigten sich ebenso oft geringe Zunahmen wie geringe Abnahmen der Herzschlagfrequenz. In Widerspruch mit den Befunden früherer Forscher standen die beobachteten beständigen [consistent] Abnahmen der pH-Stärke [hydrogen ion concentration] des abgesonderten Speichels.

Auch subtilere Reizarten erzeugten Veränderungen der Reaktionsgestalt [pattern of reaction]. Das Einatmungs-Ausatmungsverhältnis nimmt, z. B., ab, wenn widerliche Situationen dargeboten werden, und zu, wenn esthetische Reize gegeben werden.

Die Veränderlichkeit [variability] ist bei allen beobachteten Reaktionen differenzierend. Bei verschiedenen affektiven Reaktionsarten zeigten sich verschiedene vollständige Gestalten [complete patterns] sich in gleichzeitig einhergehenden Veränderung äussernd [a complete pattern in terms of concomitant variability]. Es liess sich der Reiz leicht aus der Gestalt der polygraphischen Registrierung erkennen. Eine Ausdehnung und Anwendung dieser Untersuchungsmethode, zur Bestimmung der gleichzeitig einhergehenden Veränderungen [amount of co-variation] bei verschiedenen physiologischen Reaktionsarten in affekterregenden Gelegenheiten [emotional situations] würde eine ziemlich vollständige Analyse des Verhaltens bei Gemütsbewegungen ermöglichen.

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**Child Behavior, Animal Behavior,
and Comparative Psychology**

DEVELOPMENT OF BEHAVIOR IN THE FETAL CAT*

From the Psychological Laboratory of Brown University

By

J. D. CORONIOS

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I

INTRODUCTORY STATEMENT

The behavior of a living organism at any moment may, temporarily, be "explained" by any one of a series of relationships or correlations. Ultimately the total series of relationships may be said to "explain" the observed behavior adequately. So far as the psychologist is concerned the relationships between the stimulus situation, the organism, and the response are of the greatest importance. These relationships may be genetic sections or cross sections of the behavior in question. That is, the behavior of a living organism at any moment may be "explained" by correlations involving the essential factors in the stimulating situation at the time, the psychophysiological condition of the organism, and the past history of the organism. Such a view emphasizes the genetic or developmental method as a psychological approach to an understanding of behavior. It is only in recent years, perhaps, that the developmental method has become a directing force in the experimental attack of the problems of behavior.

For the most part, in the past, many psychologists have utilized classifications of the behavioral acts of an organism at birth as the starting-point (the behavioral zero, so to speak) for the subsequent "explanation" of the behavior in the adult organism. Now there is no particular reason why the study of behavior should force the psychologist to begin at this point. There is, moreover, definite evidence why such investigations should begin with a prenatal ontogenetic zero (15, 29). It is only in the past few years, perhaps, that vigorous and extended efforts have been made to investigate experimentally the long and complicated behavior development before birth.

In the past, the activity of the organism at birth, or very soon after, has often been referred to as innate. No attempt was made to describe or investigate experimentally the behavior which may be observed in the prenatal period. Much behavior subsequently following upon this has been designated as acquired. The activities observed at birth have been variously classified into instincts and reflexes. The length of the lists, the types of the classification, and the criteria for their determination have depended, perhaps, upon the systematic temperament of the writer. The acquired forms of behavior have been described and classified as habits. Such forms of behavior are, in a sense, opposed to the instincts, since the habits have been acquired in the postnatal lifetime of the organism.

In order to "explain" the manner in which habits have been acquired many theories have been proposed. Whatever the particular way in which one may "explain" the complicated process of the acquisition of behavior acts, each has attempted to account for, in a generalized way, the complex behavior activities of the adult organism. A complete "explanation" of such behavior will involve a large series of correlations.

In general, however, the psychologist has not had much to say concerning the behavior which, one may say, has been acquired in the prenatal lifetime of the organism. Attempts at such "explanatory" correlations have been made with more or less success by the geneticist in the field of biology. The "explanatory" correlations which the geneticist has made have dealt largely with the relationships between the properties of certain protoplasmic materials (the genes of the chromosomes) and the appearance of certain adult characteristics sometime after birth.

Although it is advisable and extremely advantageous to make such correlations, there are a host of other relationships which exist intermediate to such correlations. These are of the greatest importance for a psychological understanding of the complete development of behavior in the living organism. Because of this relative lack of emphasis upon, and lack of knowledge concerning, the development of behavior during the prenatal period, the present investigation of the development of behavior in the fetus of the cat was undertaken.

The purpose of this investigation was, then, the determination of the precise qualitative nature of the development of behavior in the prenatal lifetime of the cat, or, conversely, the tracing back to its prenatal inception the characteristic behavior of the newborn kitten.

II

EXPERIMENTAL MATERIAL, METHODS, AND APPARATUS

A. The Experimental Animal

The cat was chosen as the experimental animal for several reasons. For many years the cat has been a common laboratory animal in biological and physiological research. Consequently a large literature has accumulated, especially about its anatomical structure and, to a lesser degree, about many of its physiological functions. Inasmuch as an understanding of behavior demands a more or less complete knowledge of the structure and function of the recepto-neuro-muscular mechanism, it is readily seen that such information is of value to the animal psychologist.

Since the pioneer researches of Thorndike, the number of experiments on the behavior of the cat has been relatively small (1, 28, 68, for bibliographies); yet what has been done indicates that it is a profitable field for further investigation. For many years comparative psychologists have emphasized the fact that an understanding of behavior must, among other things, include a thorough description of the genetic history of the organism's responses; yet, as has already been indicated, little research of that nature has actually been undertaken in the past.

In recent years the cat has been used by several biologists in experiments on the correlation of behavior with the functional development of certain parts of the nervous system, and this has required an enumeration of the various items of the developing behavior of the kitten (1, 28, 68). Such work suggested the importance of tracing back to its prenatal incidence the complex behavior as it appeared in the kitten at birth. Without this, the picture of the development of behavior in the cat would be incomplete. This idea was further strengthened by experiments of the same nature with other organisms, thus providing a background from which to begin. The extensive researches of Coghill on the developing behavior of Amblystoma, those of his students, Swenson and Angulo y González, on the rat fetus, the investigations of Preyer and of Avery on the fetus of the guinea pig, and those of Minkowski with the human fetus are, perhaps, the more notable systematic efforts to trace behavior back to its prenatal inception. The work of these men should indicate to the psychologist the importance and necessity of employing the genetic method in behavior investigations. Finally, an experiment by Brown (14) demonstrated the feasibility of attempting a systematic investigation of the development of behavior in the fetal cat.

B. HOUSING AND GENERAL CARE

In undertaking this investigation[1] the writer was faced with the problems of housing, feeding, and general care, about which, at the time, very little was known. An expedient method was to start the animal colony and to hope to learn from experience something about the general care of cats.[2]

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[1] The problem was first suggested in the fall of 1928 by Professor Leonard Carmichael of the Department of Psychology. A cat colony was started at once. Preliminary experiments were conducted during the winter and spring months of 1929.

The cats were housed in a large, well-lighted, well-ventilated, steam-heated room on the second floor of the animal laboratory. The male cats were segregated from the female cats in a portion of this room by a partition of wire mesh. The floor of the entire room was covered with galvanized iron in order to facilitate the daily cleaning of the animal quarters. Wooden shelves, a foot wide and about two feet from the floor, ran along two sides of the room. Clear, clean sawdust was liberally provided. An essential element in maintaining the health of the cats was to keep the quarters scrupulously clean at all times. The health of the experimental animals was unusually good except for a single serious epidemic of colds during the early months of 1930.[3] An attempt was made to keep the room temperature between 70° and 80° F. and to avoid great fluctuations of temperature. Captive cats seem especially susceptible to colds; consequently damp, drafty quarters must be avoided.

A standardized diet for cats has not yet been developed.[4] Throughout the duration of this experiment an ordinary kitchen-scrap diet was used. The scraps were supplied by the college cafeteria and by restaurants in the neighborhood of the university. The kitchen-scraps consisted of good, wholesome pieces of various meats—beef, chicken, lamb, and occasionally calf's liver. The quantity was variable but always sufficient to meet the needs of the colony. The cats were also given warmed cow's milk daily, about two quarts to thirty cats. In addition, from time to time, each cat was given 5-15 cc. of cod-liver oil. The animals were fed once a day, in the evening, throughout the year. The food was allowed to remain in the pans during the night and the excess was removed when the quarters were cleaned the next day.

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[2] Many important and helpful suggestions as to the general care of cats may be found in Adams (1).

[3] When cats were seriously affected with colds nothing could be done for them. It was then advisable to dispose of them humanely in order to prevent the spreading of the infection. Cats not so seriously affected were immediately isolated in a separate room provided for the purpose.

[4] A diet developed by Adams (1) is no longer recommended.

Under this diet, with the one exception noted above, all the cats were in good health. All of the cats had a sleek coat of fur and, although no weights were taken, none seemed to lose weight under these conditions.

C. THE PERIOD OF OESTROUS AND RELATED FACTS

The season of the year when female cats are sexually active, the number and duration of oestrous periods, the time elapsing between copulation and fertilization, and the ways of ascertaining when the female cat is sexually receptive all had to be known before the investigation could begin.

Very little study has been made of the sexual activity of the cat. Such work as has been done indicates that the domestic female cat may have from two to four sexual periods during the year (45, pp. 139-172). From the writer's own observations, sexual activity in the female cat may occur between December and September. The intervening period, between the last week in August and January, is, in so far as the writer has observed it, entirely one of sexual inactivity. The sexually active period is at its height during the months of January, February, and March.[5]

The behavior of a cat in heat has been described by Van der Stricht (67, pp. 367f.). "A cat in heat shows very characteristic movements. Generally she makes a specific kind of cry while at the same time she stretches her body, the abdomen curved against the ground, the posterior members flexed and the posterior part of the trunk elevated and animated with a continuous movement, accompanied by a waving of the tail. . . . One is ordinarily aware of this fact [that copulation has taken place] by a cry or several sharp, piercing cries of the female; the male withdraws quickly and the female continues to roll in all directions against the ground." However, it has been the writer's observation that not every cat which is in heat manifests it in external behavior. Because of this fact, it becomes necessary, from time to time, to allow the males to have free access to all the females. Then the willingness or unwillingness of the female to accept the male will indicate whether she is in heat or not.

At various intervals of the period of heat, just before, during the first, second, and third day, or at the beginning of heat, Van der Stricht (67) sacrificed 37 female cats and with an appropriate technique examined the ova of the sacrificed cats. The following conclusions pertinent to the present problem were reached:

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[5] The earliest recorded pregnancy was noted in a cat in which copulation took place on December 28; the latest one occurred in a cat in which copulation took place on August 21.

1. The period of heat lasts generally for from two to three days (presumably after copulation).
2. Ovulation is induced by copulation.
3. The period of ovular fertilization coincides approximately with the end of the period of heat (at the end of the second or third day).

These conclusions have, in general, been confirmed by others working in this field (30, 67, 45).

The ages of the fetal cats have been determined on the basis of this experimental evidence. Instead of calculating the age of the fetuses from the time of copulation, in each case an allowance of two days was made from the time of copulation. For example, if copulation occurred on February 2 and the female cat was used for experimentation on February 26, the age of the embryos was calculated as 24 days from the time of copulation minus two days, thus 22 days. This was done to allow for the probable time elapsing between copulation and fertilization. In every case, then, the ages of the fetal material are reckoned in accordance with this formula, unless otherwise stated. The gestation period in the cat is about 62 days from the time of fertilization.

D. APPARATUS

In making this investigation it was necessary to be able to observe for a number of hours the fetal material under approximately normal conditions, with the umbilical circulation intact and under a controlled temperature of 37.5° C. ± .5° C.[8] To insure such optimal conditions a special technique was employed and an appropriate bath-apparatus was devised.

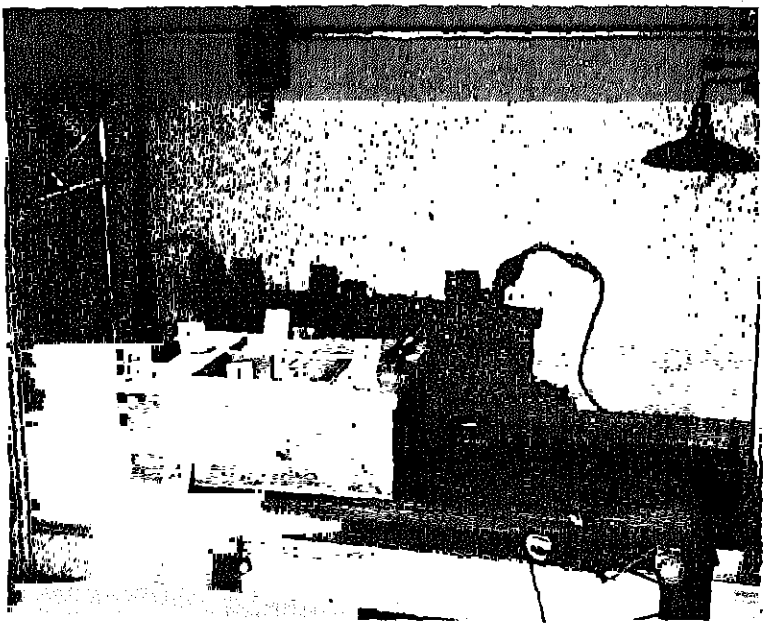

FIGURE 1
THE BATH-APPARATUS

The bath-apparatus consists of two detachable units (Figure 1). The bottom unit (*A*) is a galvanized iron tank, 23.75 x 20 x 9.25 inches. The top unit (*B*), which is made of tin and coated with white enamel throughout, has two shallow compartments separated by a partition with a 3-inch opening. The outside measurements of the large rectangular compartment (*1*) are 12.5 x 10.75 inches. The other compartment (*2*) is 12.5 inches long and 6.25 inches wide. It has a gradually sloping bottom which is 3 inches at the point of greatest depth.

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[8] Adequate reasons will be given later in the paper for the use of this procedure.

The top unit has three openings through which are inserted a thermo-regulator (*3*) and two heating elements (*4, 5*), all of which are removable. The thermo-regulator is a De Khotinsky bimetallic, electric, water-bath type effecting a temperature control within .5° C. The heating elements are two knife-type immersion heaters, one of 125-, the other of 250-watts capacity. Figure 2 illustrates the wiring of the bath-apparatus.

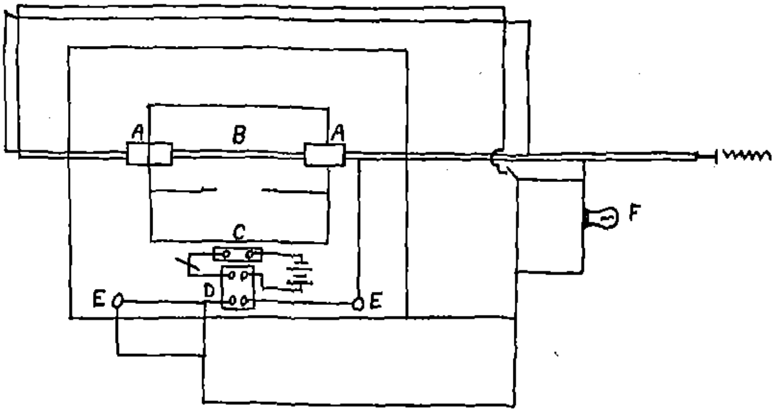

FIGURE 2

THE WIRING OF THE BATH-APPARATUS

A—heating elements
B—bath
C—thermo-regulator
D—relay
E—condensers
F—pilot light

When the bath-apparatus is in use it rests on a wooden table. The bottom unit of the bath-apparatus is filled with tap water. The two compartments of the top unit, which fits over and rests upon the tank, are filled with physiological salt solution.[7] The thermo-regulator and the two immersion heaters are inserted in the proper openings and are immersed in the tap water of the tank. After this, the salt solution is allowed to come to the required temperature of 37.5° C. before being used in the experiment.

An arrangement (Figure 1) was also provided for making motion-picture records of the fetal behavior. The framework of this set-up consists of three iron rods. Two of these rods (47 inches long and .75 inch in diameter) are clamped to the ends of the table, one at each end, in a vertical position. By using the appropriate clamps, the third rod (54 inches long and .75 inch in diameter) is laid horizontally between the two upright rods. Attached to the horizontal rod is a universal clamp to which the motion-picture camera is screwed in place directly above the bath-apparatus. This arrangement makes it possible to obtain the optimal distance with the lens-setting used in each case.

To secure the proper distance in the vertical plane, the two upright rods are either lowered or raised by sliding them through the clamps. On the horizontal plane the holder to which the universal clamp is attached is moved to the left or to the right until, by sighting through the view-finder of the camera, the correct field is secured. Two reflectors with spot-light attachments and with two lamps, each of 500-watts capacity, provided ample illumination to the field. A 2-inch F 3.5 lens was used for photographing the early stages and for taking close-up photographic sequences. For the more advanced stages of prenatal development a 1-inch F 3.5 lens was used. The camera used was a Bell-Howell 70-D (20, 21).

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[7] The solution was made from the formula of Ringer-Locke, with the glucose omitted. It had the following composition: .015% $NaHCO_3$, .024% $CaCl_2$, .042% KCl, .92% NaCl, 99% distilled water (10, p. 211).

E. OPERATIVE TECHNIQUE

The pregnant female to be decerebrated was firmly and securely tied to a cat-board. Surgical ether was administered by a cone. A ventral incision was made in the neck, both carotid arteries secured and ligated in turn, and a cannula inserted into the trachea. The cannula was employed in case artificial respiration had to be used. After opening the skull by trephining, the dura mater was slit and the mid-brain was sectioned following the bony tentorium as a guide. After this operation the administration of ether was *immediately discontinued*. Parts of the brain anterior to the cut were removed and small pellets of cotton were inserted to check the bleeding. The average time of this entire operation, during which ether was administered, was 13.5 minutes (Table 1).

After decerebration the cat was allowed to remain quiet for from an hour and a half to two hours to allow the effects of the anaesthetic to pass away. During this recovery period a superficial mid-line abdominal in-

TABLE 1

Age in days	Ether administered (time)	Loss of blood (quantity)
21	10 mins. 10 secs.	30 cc.
23	8 " 20 "	15 "
24	10 " 45 "	15 "
25	13 "	15 "
26	13 "	15 "
27	10 " 13 "	30 "
28	18 "	9 "
29	10 "	45 "
30	10 "	45 "
31	9 "	24 "
32	8 " 50 "	15 "
34	10 "	15 "
36	*18 "	24 "
38	12 "	30 "
40	12 " 30 "	30 "
43	14 " 10 "	15 "
45	*23 "	15 "
46	9 " 15 "	15 "
47	14 "	30 "
49	*21 "	9 "
51	*25 "	9 "
53	*24 "	9 "
55	*18 "	15 "
58	11 "	24 "

*These were the first performed.

cision was made. After this lapse of time, the cat was placed in compartment 2 of the bath-apparatus with only the lower trunk immersed in the salt solution.[8] A deep abdominal incision was made along the linea alba. One horn of the uterus was then lifted out from the body cavity into the salt solution. One fetus at a time was shelled out into the solution, special care being taken not to exert tension on the umbilical cord.

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[8] In the case of very young stages (21-32 days) the decerebrated female was placed directly in compartment 1 of the bath-apparatus. This was done because at this time the uterine horns of the pregnant female are so small that they will not extend through the opening between the two compartments and would thus tend to impair the observations of the fetal reactions.

Under these conditions observations and motion-picture records were successfully obtained from the embryos and fetuses of 32 pregnant cats. A pre-arranged outline was followed to facilitate and systematize the observations. In the later stages, after tying and severing the umbilical cord of the fetuses, they were transferred onto an electric heating pad and observations of their behavior in air were made.

Besides these observations, the lengths (crown-anus) and the body weights have been filed, together with the

TABLE 2

No. of litters at each age	No. of fetuses in each litter	Age in gestation days	Average length in mm.	Average weight in gms.
1	4	21	13.6	.250
1	3	22	16.5	.325
1	5	23	19.2	.525
1	4	24	20.6	.538
1	3	25	23.6	.738
1	4	26	25.2	1.130
1	3	27	28.6	.598
1	5	28	23.9	.625
1	3	29	38.0	2.43
1	5	30	39.0	2.57
1	4	31	43.1	3.22
3	3, 5, 4	32	43.4, 45.7, 46.2	3.30, 3.50, 4.60
2	4, 6	34	54.6, 54.0	5.57, 5.50
2	4, 4	36	60.2, 62.6	7.65, 8.22
1	4	38	69.8	13.17
2	4, 6	40	77.5, 79.9	16.62, 17.45
2	2, 5	43	89.0, 91.6	28.80, 27.54
1	4	45	87.5	32.55
1	5	46	96.2	38.76
1	5	47	112.8	50.60
2	5, 2	49	111.0, 109.0	47.86, 44.30
1	5	51	121.4	66.16
1	3	53	127.3	83.20
1	5	55	125.8	81.92
1	5	62	133.4	86.10
5	2, 1, 1, 5, 4	58	147.0, 148.0, 150.0, 144.4, 149.0	119.50, 116.50, 101.50, 107.54, 122.44

written protocols (39-42). The embryos and fetuses have been preserved in an appropriate solution of formalin. The distribution of weights and lengths may be studied from Table 2 and from the accompanying graphs (Figures 3 and 4).

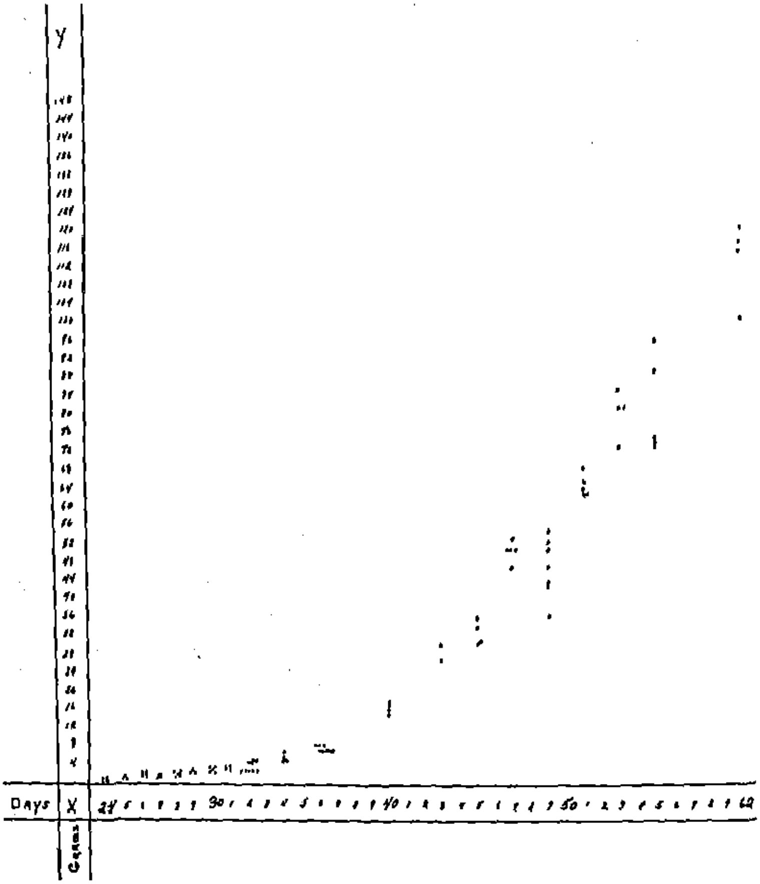

FIGURE 3

Distribution of Weights According to Age in Gestation Days

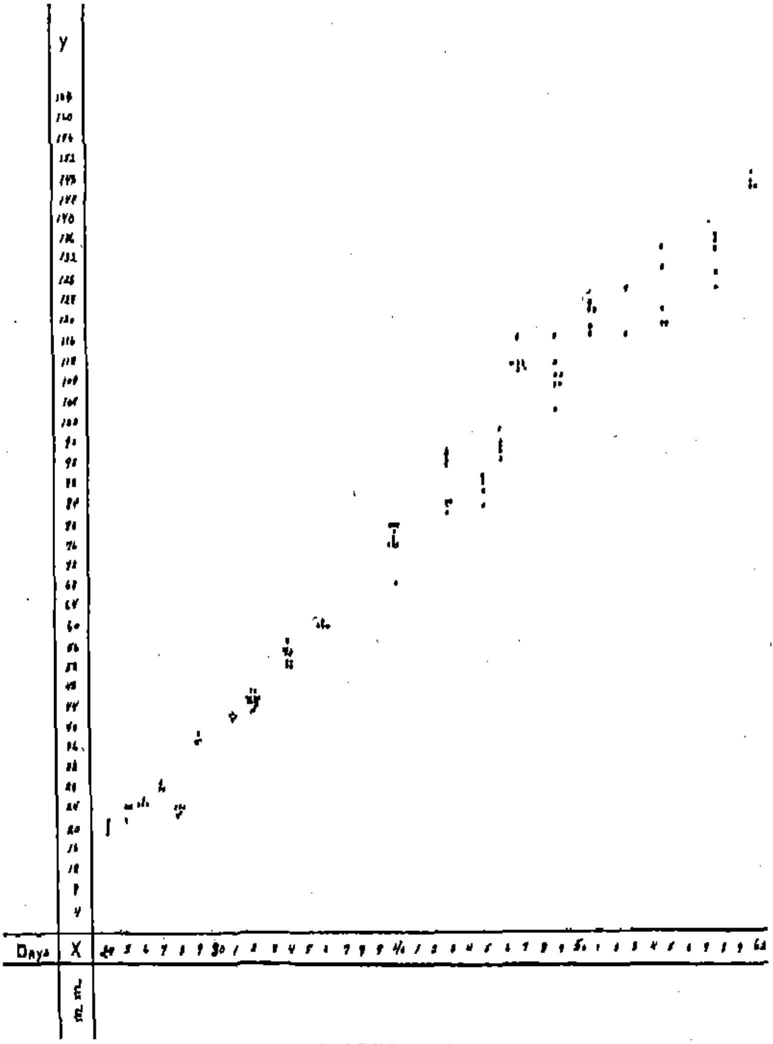

FIGURE 4

Distribution of Crown-Anus Lengths According to Age in Gestation Days

III

HISTORICAL REVIEW OF THE LITERATURE

A. NON-MAMMALIAN STUDIES

1. *Amblystoma.* It is not the aim of the writer in the present paper to deal exhaustively with the investigations of the early behavioral development of organisms other than mammals. However, the complete and systematic investigations of Coghill with Amblystoma are important for a proper orientation in the present study. Recently Coghill (18) has conveniently summarized the main results of his work on Amblystoma. He has traced the development of behavior acts in the order in which they appear. He deals with aquatic locomotion, terrestrial locomotion, and the feeding reaction (18, pp. 5-38). There are, according to Coghill, five physiological stages which eventually lead to aquatic locomotion: (1) non-motile stage; (2) early flexure stage (bending of head to one side); (3) coil stage (bending into single tight coil); (4) S-reaction (reversal of coil before complete execution); (5) S-reaction in series sufficient to effect locomotion (18, p. 9).

After aquatic locomotion the course of development leads to an attainment of terrestrial locomotion and of the feeding reaction. Of these the development of terrestrial locomotion is of special interest in the present study because it may be compared with the development of locomotion in the fetal cat.

An important aspect of the establishment of the walking reaction is the cephalocaudal progress of the development of the component parts. Anatomically and behaviorally, the forelimbs develop earlier than the hind limbs. The earliest forelimb movements occur only as the trunk moves this way or that. Later, the forelimbs begin to move independently of the trunk but only as a unit. As time passes, individual divisions of the forelimb begin to move, first as the whole limb moves, later as an independent unit. The progress of development in the hind limbs is similar to that occurring in the forelimbs but at a time ten or twelve days later. Alternate coordinated beats of the forelimbs appear first. As development progresses further, this coordination invades the hind limbs. So the nicely timed rhythm of walking is not an all-or-none affair but a gradual development. At first the two forelimbs are extended and flexed simultaneously. Later, as independent beats appear, they seem to be under the control of the trunk. When the forelimbs have developed to the point where an alternate trotting rhythm is established, the hind limbs are moving together after the fashion of the forelimbs in their early development. On the basis of his studies Coghill concludes in part that:

> "*a.* The behavior pattern develops in a regular order of sequence of movements which is consistent with the order of development of the nervous system and its parts.
> "*b.* Behavior develops from the beginning through the progressive expansion of a perfectly integrated total pattern and the individuation within it of total patterns which acquire various degrees of discreteness" (18, pp. 36f.).

B. MAMMALIAN STUDIES

1. *The White Rat.* The earliest recorded study of the fetus of the white rat, of which the writer is aware, is a monograph by Lane (36). Beginning with fetuses of 7.5-mm. crown-rump measurement and extending to young animals 16 or 17 days after birth, Lane investigated the functional development of the sense-organs. The fetuses were delivered into a dish of warmed salt solution. The uterus had previously been excised from the mother. The observations were then carried out in a warm observation chamber. Although, according to Lane, one should make allowance for the fact that there is a certain amount of overlapping of the periods of development, the order in which the sense-organs attain their functional capacity is as follows: (1) touch; (2) equilibrium; (3) smell; (4) taste; (5) hearing; (6) sight. Of these, however, only touch and equilibrium become functionally active in the prenatal period of development. Smell and taste are possibly functional on the first day after birth. Reactions to sound are first obtained on the 12th day after birth and to light on the 16th or 17th day after birth, or when the eyes are opened.[9]

Lane also conducted a parallel investigation of the nervous system, central and peripheral, and of the sense-organs to ascertain histologically their structural development at the time when the function is first apparent.

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[9] Although it was Lane's purpose to investigate the development of the sense-organs only, his published protocols contain descriptions of the behavior elicited at the various stages by the stimuli employed. These results are not reproduced here because of the important gaps left unobserved.

The histological examinations have led Lane to conclude that, since the afferent, efferent, and associational pathways are already laid down and yet the rat cannot respond to the stimulus used, *the block in the circuit is the exteroceptive end-organ.* When this receptive organ develops its functional capacity the nerve circuit is complete and response to the adequate stimulus appears.

In 1925 Swenson (61) reported a method for making experimental observations on white-rat fetuses. The following procedure was used. The pregnant animal is anaesthetized. The two carotid arteries are secured and ligated. The right and left external jugular veins are tied close to where they empty into the innominate veins, and the ether is discontinued. The animal is then transferred to a constant-temperature bath of 38° C. salt solution where the fetal observations are made.

However, in a study of fetal responses which Swenson was carrying on at the time, he found it necessary, from time to time, during the actual observations of the fetal material, to administer a few drops of ether to the mother in order to prevent her moving (62, p. 12). This fact is not mentioned in the published article previously cited.

Beginning with the 364th hour of gestation (15 days and 4 hours), Swenson made a more or less continuous study of the movements of 117 fetuses from 26 litters. These observations were extended to the 408th hour of gestation. Fetuses of 20 litters after the 408th hour have also been studied; these investigations do not carry through to birth, however (62, p. 13). Incidental observations were also made of general irritability to mechanical stimulation and of spontaneous movements (62, pp. 168-178).

Swenson has classified the order of appearance of fetal behavior in the albino rat beginning with the first observed movement, which is a lateral flexion of the head, into three stages. These stages of development occurred during the 16th day of gestation. The stages classified follow (62, pp. 189-191):

A. The non-motile stage
  1. Appears to end at or near the 378th hour of gestation, i.e., 15 days plus 18 hours

B. Early motile stage
  1. Appears to begin at or near the 378th hour of gestation and to end at or near the 390th hour, i.e., 16 days plus 6 hours
  2. The movements observed here consisted of:
    a. Lateral flexion of the head, trunk, and rump
    b. Alternate lateral flexion of the trunk, head, and rump
    c. Forelimb backward and forward movement
    d. Flexion and extension of the forearm
    e. Hind-limb abduction and adduction

C. The dorso-ventral extension-flexion stage
  1. Appears to begin at or near the 390th hour of gestation and to end at or near the 408th hour, i.e., at the end of 17 days
  2. The movements of the head consisted of:

   a. Head extension—was a passive movement caused by lateral flexion of the trunk
3. The movements of the trunk consisted of:
   a. Lateral flexion
   b. Alternate lateral flexion—which was the dominant movement and continuous for long periods
   c. Maintained lateral flexion—the duration was 3 or 4 seconds
4. The movements of the rump consisted of:
   a. Lateral flexion
   b. Alternate lateral flexion } were essentially part of trunk movements
   c. Ventral flexion—was the most powerful of all the movements
   d. Extension—was a vigorous movement
5. The movements of the forelimbs consisted of:
   a. Forward and backward movement
   b. Flexion and extension of forearm
   c. Flexion of the paw
   d. Probable maintained backward extension
6. The movements of the hind limbs consisted of:
   a. Abduction and adduction
7. The movements of the mouth consisted of:
   a. Mouth-opening and closure or lowering and raising of the lower jaw
8. The movements of the tongue consisted of:
   a. Protrusion and retraction
9. The movements of the skin over the rump consisted of:
   a. A feeble contraction of the skin

D. Later stages (or rotation stage) (63, p. 31)[10]

1. 18th-day fetus (presumably beginning at or near the 408th hour). "The new movements exhibited by this fetus were rotation of the rump, extension of the tail, and backward movement of the hind limbs" (62, p. 165).
2. 19th-day fetus. "The following movements were the new movements this fetus exhibited: ventral flexion of the head was a discrete movement; tongue protrusion was maintained at times; maintained lateral flexion with maintained rotation of the trunk was noted; rotation of the trunk and rump to the right or left side; maintained extension of one fore limb and flexion at the elbow of the other fore limb; extension of the hind limb as a whole; flexion and extension of the hind limb; quick movements, probably constriction movements, of the thorax and abdomen. The posture attempt was especially prominent" (62, pp. 165-166).
3. 20th-day fetus. "Respiratory movements observed; not rhythmic. They do not become rhythmic after the fetus is removed from the solution. . . . Extensive development of tongue movement. Rump rotation in direction opposite to rotation of the head" (62, pp. 166-167).

From this study of the developing behavior of the albino-rat fetus this author concludes: "Movement in the rat fetus develops in an orderly manner. . . . Development is undoubtedly cephalocaudad. . . . Development of movement in the fore limbs and in the hind limbs was unquestionably proximodistal. . . ." (62, p. 187).

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[10] A later classification.

With the aid of the motion-picture camera Swenson has recently traced back to their earliest beginnings the "crucial" movements of progression, respiration, and ingestion (64, 65). Progression is the first to appear. Next, in order of appearance, is respiration, closely followed by ingestion. Swenson concludes: "Each simple movement makes its first appearance in a definite order with relation to the other simple movements. Once a simple movement has appeared, it persists in kind of movement, but its qualities change with the development of the animal" (65, p. 40). Further, he says, "The contraction of any simple movement at the time of its first appearance is feeble and slow, but with development it becomes quicker and stronger, and later sustained contraction appears" (65, p. 40).

Several brief reports of the developing behavior of the albino-rat fetus have been made by Angulo y González. He also used the motion-picture camera to obtain records of the typical stages of behavior development in rat fetuses from the time when behavior is first observed to the time just before birth (2, 6). The following stages were investigated: (1) lateral flexion of the trunk; (2) flexion of the trunk with movement of the forelimb; (3) extension of the trunk; (4) maintenance of contractions; and (5) beginning of emergence of independent movements; also specific reflexes and postural reactions. Fetuses at 15, 16, 17, 18, and 19 days after insemination were examined for their behavioral development as well as for the progressive increase of the motor-cell columns in the cervical region of the cord (2, p. 46). The histological examinations show that ". . . there is a progressive segregation of the motor cells coincident with the orderly increase of the motility of the fetus" (3, p. 17).

In a more recent and more elaborate investigation Angulo y González (8) investigated rat fetuses 14, 15, 16, 17, 18, 19, 20, and 21 days after insemination. Extensive motion-picture records were made during the course of the experiment. A brief summary will be given of the more important results obtained from this experiment.

A. Fourteen days (336-359 hours)
  1. Non-motile

B. Fifteen days (360-383 hours)
  1. Lateral-flexion stage—first sign of motility at 378 hours after insemination
     a. "The movement consisted of a slight bending of the head, involving only the neck region, which took place only after stimulation of the snout" (8, p. 402). ". . . the activity ceases almost immediately after the first response. Stimulation upon any other part of the body fails to arouse the fetus. . . ." (8 p. 404).

C. Sixteen days (384-407 hours)
  1. Movement of the forelimbs with movement of the trunk

a. Lateral flexion of the trunk more frequently observed; also more pronounced and stronger.

b. Movement progresses so as to involve first the forelimbs and later the rump. Movement of the hind limbs is added to this movement in the older fetuses of this period.

c. Forelimbs move only with the trunk.

d. Total mass reaction involving trunk and forelimbs quite frequent.[11]

D. Seventeen days (408-431 hours)

1. Head-extension stage

a. ". . . the movement more often obtained was a total mass reaction which consisted in extension of the head with opening of the mouth and protrusion of the tongue. This movement spread also in a cephalocaudal direction, involving the forelimbs and the rump region, but when the forelimbs were involved in this movement, they did not move as in the previous stage; that is, one limb raised and the other lowered. In this case both fore limbs were retracted at once" (8, p. 411).

b. Total pattern (or mass reaction) of lateral flexion of the trunk and rump with fore- and hind-limb movements. This is stronger than in the previous stage and has spread in a proximodistal direction so as to involve the forearms and hands.

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[11] A total mass reaction consists of a primary or basic movement and a series of secondary movements.

- *c*. Ventroflexion movements of the head and rump
- *d*. Rotation of the trunk and rump
- *e*. High degree of spontaneous activity
- *f*. Responded to stimulation of the side, of the forelimbs and hands and of the snout.
- *g*. Responses not discrete reflexes but mass reactions.

E. Eighteen days (432-455 hours)

1. Stage of maintained contractions
   - *a*. In the previous stages active contraction was followed by a quick relaxation. At this stage the contractions are maintained for several seconds.
   - *b*. The total pattern of lateral flexion disappears at this stage and is supplanted by head extension. This reaction has traveled caudad so that, now, the rump and hind legs are involved in the movement.
   - *c*. It is possible that as this pattern spreads to the caudal region a differentiation takes place in the anterior region so as to cause a separation of the secondary movements during periods of activity of the primary movements. This is not a complete breaking-up of the total pattern but merely an inhibition of the secondary movements.
   - *d*. At this stage there was noted a high degree of independence of the rump region from

the general total pattern of lateral flexion, and there frequently appeared lateral flexion of the rump independent of lateral flexion of the trunk.

e. The forelimbs move as a whole independent of the trunk.

f. Independent flexion and extension of the hand is present at this stage.

g. Opening of the mouth independent of head extension and movement of the hind limbs independent of the rump also present at this time.

h. The independence of the secondary movements is acquired in a cephalocaudal and proximodistal direction.

F. Nineteen days (456-479 hours)

1. Stage of specific reactions
   - *a*. At this stage one can, in general, predict the type of response in relation to the place stimulated.
   - *b*. Stimulation of the dorsal side of the hand always causes hand extension; stimulation of the volar side of the hand always causes hand flexion.
   - *c*. The independence of the secondary movements from the total pattern is a condition which is relative to the pattern as a whole, while the specificity of reactions is related to the place of stimulation.
   - *d*. Cross and diagonal reflexes which are also

specific to place stimulation are also present at this time.

G. Twenty and twenty-one days (480-527 hours)
1. Period of marked activity
   a. Spontaneous activity is very rare and when it does occur it does not involve violent reactions.
   b. Discrete reflexes are difficult to evoke at this time.

A minute anatomical examination of the forelimb of the albino-rat fetus at about the time in its development when movement first begins was made by Blincoe (11, 12).

Behavioral observations of the albino-rat fetus and of a hooded strain, incidental to the main problem of a study of regeneration, were also made by Hooker and Nicholas (32). In general, their observations confirm those made by Swenson and Angulo y González.

Corey (19) has recently reported an investigation in which he sought to determine the factors which bring about the first movements of respiration in the albino-rat fetus. "It is concluded that the initial inspiration is normally brought about by an increased carbon dioxide tension in the blood, aided by the stimulating effect of the drying of the skin" (19, p. 41).

2. *The Rabbit*. By employing a technique much like the one used in the present study of fetal cats, Pankratz (54) was able to observe the development of behavior in the fetus of the rabbit. He writes: "Spontaneous motility and movements elicited by mechanical stimulation of the nose, head and neck regions were

first observed in 15 to 16 day old fetuses. The movements consisted of a simple lateral flexion in the neck and upper trunk. Seventeen day old fetuses showed a marked ventrolateral flexion of the head and upper trunk with some movements of the fore limbs. In 20 day old fetuses opening and closing of the mouth were observed; also active movements of the fore limbs, flexion of the hind limbs, and lateral flexion of the whole trunk. Twenty-five day old fetuses turned their heads upon stimulation, and manifested greater motility in hind limbs and trunk. Movements became more complex as gestation advanced" (54, p. 58).

3. *The Opossum.* A very interesting and unusual study of pouch-young opossums has been made by Langworthy (37). Since the latter part of the fetal development of these animals takes place in the pouch of the mother, exceptional advantages are provided for making a continuous study of their behavioral development. In this study Langworthy is particularly interested in studying the progressive myelinization of nerve tracts and only incidentally in the behavioral aspects of these animals. Partly, perhaps, because of this fact, and partly because of the difficulties in obtaining enough material, the prenatal stages have not been studied, thus omitting a most important phase in a study of the development of behavior.

Observations of behavior were made on pouch-young opossums beginning with animals less than four weeks old (time reckoned after copulation) and extending to young opossums 76 days old. The animals were removed from the pouch for study. Observations were made before and after decerebration. In each case a parallel study was made of the myelinization of tracts in the nervous system.

There appears to be a gradual development in behavior as evidenced both by the functional appearance of new behavioral capacities and by the general integration of behavioral elements already functional. The general progressive increase in behavior development seems to follow an anterior-posterior course, the cephalic end of the opossum becoming more sensitive to stimulation and showing more rapid development in the coordination of responses than the caudal end of the animal. Although Langworthy does not explicitly make interpretations such as these, several quotations will indicate that such interpretations are implicit in his findings. In 7-day-old pouch-young opossums "the fore legs were relatively large and muscular with well-developed claws; the hind legs were small with little muscular development. . . . Beats of the fore legs occurred when the animal was lying on the side, but there was little contraction of the hind leg musculature" (37, pp. 206f). In opossums less than one month old the "hind legs showed more movement than in the younger opossums, but were not at all coordinated with each other or the fore legs. The posterior part of the body moved as a unit by the contraction of the abdominal musculature" (37, p. 209). The next stage examined was that of the 36-day-old opossums. "There was scarcely any coordination in the fore and hind legs present and the hind leg movements were poorly coordinated. A crossed-extension was usually but not always obtained on pinching the foot pad of the fore leg. Stimulation of the foot pad of the hind legs caused a flexion of both hind legs" (37, p. 210). This superiority in coordination of the anterior portion of the animal over the posterior portion apparently continues until the 62nd day when the opossums begin to spend some time outside the pouch. At this stage the animal can support its body on its legs and walking appears to be present. In 64-day-old opossums the "hind legs were as well-developed and as active as the fore legs. The legs were able to support the weight of the body and walking was well coordinated" (37, p. 228).

From the histological examinations of the development of myelin, Langworthy concludes that "fibres and tracts become medulated in the order in which they have developed phylogenetically. There is suggestive, but by no means conclusive, evidence that, in general, tracts become medulated at the time when they become functional" (37, p. 238).

4. *The Guinea Pig.* Wilhelm Preyer (56) was one of the first to make extensive investigations of the physiological and behavioral processes of living organisms which may be observed during the prenatal period of development. Many of the observations were strictly physiological and need not concern us here.

Preyer began at the third week of gestation to remove guinea-pig embryos for observation. At weekly intervals his observations continued through the tenth week. Some of the observations were made on animals delivered into the air; others were made on animals delivered into a bath of physiological salt solution of body temperature. In all, Preyer observed the embryos and fetuses of 32 guinea pigs.

The first movement was observed to occur in an embryo of the fourth week. Preyer writes as follows: "Dieser Embryo ist der kleinste Meerschweinchenembryo, an dem ich Bewegungen mit Sicherheit wahrgenommen habe." The movement observed was a movement of the trunk. "Bewegte den Rumpf in situ stark" (56, p. 588). No contraction to electrical stimulation could be observed.

Fetuses of the fifth week were delivered into a bath of physiological salt solution of body temperature. Preyer (56, pp. 588-589) comments on this in the following manner. "Der nackte Embryo im Salzwasser geradeso mobil wie im Ei; aber an der Luft erloschen sehr bald alle Bewegungen; . . . ." In the sixth and succeeding weeks of the gestation period the movements became more plentiful.

In a study of the peristaltic movements of the guinea-pig fetus, Yanase incidentally reported movements he observed. This study is important here only because he, too, reports movements of guinea-pig fetuses as early as the fourth week of gestation, or about 28 days (72, pp. 355-365, 372-381).[12]

A recent study of the responses of fetal guinea pigs has been made by Avery (9). Beginning with the 45th day of gestation (presumably from the time of copulation), Avery studied the responses of guinea-pig fetuses at one-day intervals, except for the 49th and 51st days, until the 68th day (the length of the gestation period).

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[12] Yanase remarks that he has also made observations of cat, dog, and rat fetuses. He does not, however, report his findings. Nor does he indicate that further publication of such material was anticipated.

His method was to etherize the pregnant female and, after sectioning the umbilical cord, to deliver the fetuses in air for study. They were not, except in one or two cases, delivered in physiological salt solution, *nor* was the umbilical circulation maintained intact.

The earliest responses elicited by experimental stimuli appeared on the 45th day. These were a gasp and a muscular twitch to an electrical stimulus. From this time until the 68th day Avery's data indicate an increase in the number of responses elicited by experimental stimuli (Figure 5).

5. *The Cat.* Graham Brown was the first, so far as the writer is aware, to investigate the movements of fetal cats (14). Using the decerebration technique, he investigated the walking activities of four cat fetuses, near term, delivered into a dish of warm physiological salt solution, leaving the umbilical circulation unimpeded. Movements of progression were observed to occur spontaneously. They were also elicited by occluding the umbilical cord, thus inducing a state of asphyxia.

In 1929 Langworthy observed the behavior of six fetal cats which were near term.[18] The experimental

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[18] The major aspect of this study is concerned primarily with the study of the behavior of kittens from the time they are less than a day old to kittens 57 days old. Tilney and Casamajor (66) have also reported work on the development of behavior in kittens correlated with the myelinization of tracts in the nervous system.

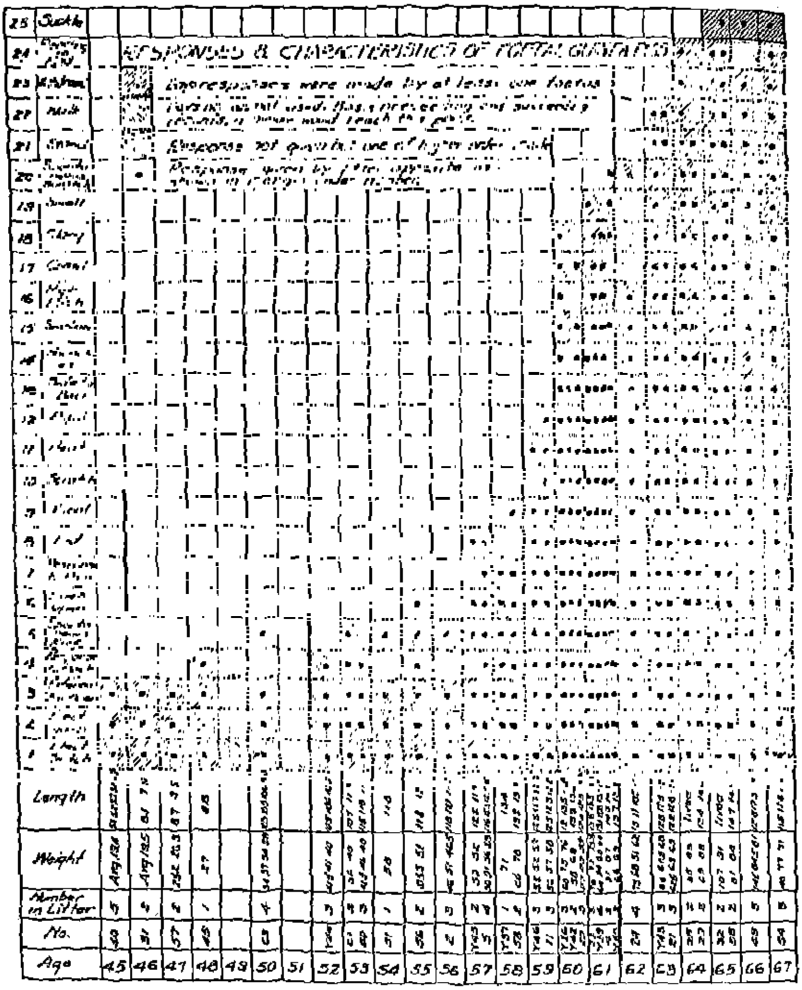

FIGURE 5

Responses and Characteristics of Fetal Guinea Pigs after the Forty-fifth Gestation Day

Age indicates length of gestation period. *No.* indicates mother's numerical designation; Y, young mother. Weight and length are given for each fetus. Responses and characteristics are numbered from bottom to top in genetic order of appearance.

[From G. T. Avery's (9) "Responses of Foetal Guinea-Pigs Prematurely Delivered." *Genet. Psychol. Monog.*, 1928, 3, 301.]

technique was, in some respects, like the one used in the present study on the behavior of the fetal cat. Each fetus was decerebrated by Langworthy immediately upon shelling it out into the salt solution and before the observations began. One important fact issues from this study of fetal cats. Langworthy does not confirm Brown's observation of progression in the cat fetus. "Well coordinated alternate beats of the fore legs occurred, but the movements of the hind legs were less active and poorly coordinated. A study of progressive movements of new-born kittens shows indeed that Brown's findings were not accurate in this regard. For kittens are several days old before the four extremities beat in a well-timed rhythm" (38, p. 144).

More recently a systematic but relatively incomplete study of the fetal movements of the cat has been reported by Windle and Griffin (70). Successful experiments were conducted with the decerebration technique upon 16 pregnant cats whose time of copulation was known. Seventeen other animals were also experimented with but the time of copulation was not known. Of the 16 successful experiments the behavior of the fetal cats was observed beginning with the 21st day (copulation age) and extending through the 36th day. Two experiments comprised the observations made from the 36th day to the time when kittens are normally delivered at birth. These consisted of experiments with one 42nd- and one 49th-day animal. Various methods were used for studying the fetuses. Some of the cat fetuses were observed while still in the amnion and apparently *not* in the physiological salt

TABLE 3

	Neck and trunk									Forelimb					Hind limb						Intrinsic head muscles		
Copulation age	Unilateral } Flexion of head Ventral } and upper trunk	Bilateral flexion of head and upper trunk	Rotation of head	Flexion (ventral) of lower trunk	Rotation of trunk	Flexion of tail	Abdominal muscles	Intercostal muscles	Diaphragm	Passive } flexion at shoulder Active } (total flexion)	Flexion at elbow (local response)	Flexion at wrist	Adduction of limb	Flexion of digits	Movement of pelvis (trunk)	Flexion at hip	Flexion at knee	Flexion at ankle	Adduction of limb	Flexion of digits	Masticator muscles	Tongue muscles	Laryngeal muscles (phonation)
23	—																						
24+	+	—									—												
24.5	+	—	—								+ —												
25	+ +	+	+	+	—						+ +	—											
26	+ +	+	+	+	+	—			+		+ +	+	?	—		—							
27	+ +	+	+	+	+	—			+		+ +	+	—	—		—							
28	+ +	+	+	+	+	—			+		+ +	+	—	—		+	—						
30	+ +	+	+	+	+	—			+		+ +	+	+	—		+	—				+	—	
31	+ +	+	+	+	+	±	±	±	+	—	+ +	+	±	?	—	+	±	—			+	?	
33	+ +	+	+	+	+	+	?	?	+	—	+ +	+	+	+	—	+	+	—			+	—	
35	+ +	+	+	+	+	+	?	?	+	—	+	+	+	+	—	+	+	—			+	±	
36	+ +	+	+	+	+	+	+	+	+	—	+	+	+	+	?	+	+	?	—		+	±	
42	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	?	?	+	+	—
49	+ +	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	?	+	+	—

solution. Others were studied in a pan of warm physiological salt solution. These authors are not clear as to which method was used in each case (70, p. 152).

The accompanying chart (Table 3) conveniently summarizes the results of the successful observations with animals whose copulation ages were definitely known.[14] From this chart it can readily be seen that the development of behavior follows a cephalocaudal course. Further, the behavior of the fore- and hind limbs develops proximodistally, as an inspection of the chart will demonstrate. This chart tends to mask the fact of gradual increase in the development and integration of behavior, but the authors include this point in the description of their results (70, pp. 154-168).

Only incidental observations were made of the development of sensitivity to mechanical stimulation. "The first reflexogenous zone . . . . included the nose, ears, and, in general, most of the head . . . . Gradually the area spread caudally to the neck, pectoral region, fore limbs, trunk, hind limbs, and, finally, the tail" (70, p. 175).

Windle and Griffin failed to observe movements of running or walking. This fact is significant in this case because their observations, too, agree with the observations of Langworthy and fail to confirm the observations made by Brown.

Holt (31, p. 42) cites the fact that Richter "has made extensive observations on cat, dog, and rabbit fetuses enucleated several days before birth, ..." The only published references to this fact which the writer has been able to find are a monograph and a short article (58, p. 42; 59, pp. 724-728). Richter says, "We found recently in a series of experiments on the behavior of fetuses (cats) still attached to the cord that stimulation of the stomach or intestine (slight pinching) elicits very vigorous movements of the entire body." Also, "I have observed it [sucking activity] in a number of rabbit fetuses about 20 days old" (59, p. 728).

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[14] This chart was modified from the one which may be found in Windle and Griffin's article (70, p. 166). It does not include the results of observations of fetuses whose copulation age was unknown.

6. *The Human Fetus.* That the human fetus is capable of movement during its intra-uterine life is, perhaps, generally known today. Awareness of this fact, as expressed in the literature, may be traced back to a time as early as Aristotle (24, Book VII, pp. 183, 185, 190). Undoubtedly many isolated observations of the movements of the human fetus may be found scattered through the literature; particularly, perhaps, reports of single cases in which observations were made by medical men. A few unsystematic observations are cited generally in the more recent literature pertaining to this problem. Such isolated observations, among many others, have been reported by Erbkam (27), Zuntz (74), Strassmann (60), Yanase (73), Krabbe (35), and Woyciechowski (71).

Perhaps the only attempt to trace systematically the development of behavior in the human fetus is admirably demonstrated by the recent investigations of Minkowski (46-52). Less extensive observations have also been reported by Bolaffio and Artom (13).

Using a local anaesthetic, Minkowski delivered, by

Caesarean operation, 22 human fetuses for study. In four additional cases the fetuses were delivered under general ether-chloroform narcosis. The umbilical circulation was maintained intact and the fetus was placed in a vessel of 40° C. physiological salt solution. This solution was renewed from time to time in an attempt to keep the temperature constant.

The youngest fetus investigated measured 5 cm. in length. Its age was estimated, on the basis of physical growth charts, to be approximately two months. The oldest fetus investigated measured 32 cm. with an estimated age of 6 months.

Minkowski has recorded his observations of the movements of the human fetus under the following headings:

1. Movements of the head, trunk, and extremities
2. Reflexes
   - *a.* Skin reflexes
   - *b.* Tendon reflexes
   - *c.* Deep neck reflexes
   - *d.* Labyrinthine reflexes
3. Mechanical muscle irritability
4. Heart beat
5. Relation of movements to fetal nervous system

Minkowski has not systematically classified the observed movements of the human fetuses according to their ages. He has given a summarized description of the behavior of the human fetuses and only incidentally did he point out differences in behavior with increase in gestation age. The dominant feature of the movements of the younger fetuses seems to be characterized by their diffuseness and variability. In older fetuses the behavior becomes less variable, assuming a more regular character, and the tendency of excitation to irradiate or spread to other parts of the body tends to disappear.

Minkowski has given us a vivid description of the movements of the head, of the trunk, and of the extremities. "The head turns to one side or to the other, is raised or lowered, the trunk bends and straightens again, and the extremities are raised or lowered, are flexed or extended, they withdraw from the trunk or are drawn to the trunk, or movements of rotation are made outward or inward. These movements are slow, unsymmetrical, arhythmic, uncoordinated, diffuse and amorphous, of small amplitude, and with a tendency of the members to return to the position from which they started; they extend to a single articulation (for example, to the shoulder, to the elbow, to the wrist, to the hip, to the knee, etc.) or to several, to a single member or to several members simultaneously, sometimes it is the proximal part of the extremities which is most active, and sometimes the distal part; in one case (in an 8.5 cm. fetus) I have observed small, isolated movements of the fingers as well as a rapid trembling of the thumb; in another (20 cm.) also movements of the fingers. . . . From time to time, especially when one applies external stimulation, these small and slow movements are cut in upon by movements stronger and more rapid, more intense, and of a greater amplitude, . . . ; this type appears more frequently in the older fetuses (from 4 to 5 months) whose movements show at the same time an increasing tendency to assume a more regular character, the two arms or the two legs moving in a manner more or less coordinated, simultaneous or alternating" (48, p. 1111-1113).

Tactual stimulation of the under lip or tongue released *mouth movements*; *brushing the* abdomen elicited contraction of the skin; and touching the still closed eyelid released a contraction of the orbicular muscle.

From the investigation of the skin reflexes, Minkowski concludes: "In general one can say that each part of the skin can serve as a reflexogenous zone of very variable motor reactions, remote or near, having the tendency to irradiate more or less to the whole of the fetal organism. In the older fetuses examined (3 to 5 months) the motor reactions determined by external stimulation are somewhat more constant, and their tendency to irradiate to other members is somewhat less pronounced, the stimulation of one hand, for example, sometimes determines a reaction which is limited to the stimulated arm, but which, nevertheless, is very variable. . . ." (48, p. 1112).

The reflexes released by stimuli of deep sensibility produced by changes of the head in relation to the trunk were very variable, becoming more constant with increase in age, and occasionally the opposite effects were recorded under appropriate stimulation.

Movements were also elicited by passive changes of the body of the fetus in space. But these so-called labyrinthine reflexes, like all the other reactions investigated in the human fetuses, were very variable, with a strong tendency of the excitation to irradiate to other members of the fetal organism.

The heart beat of the human fetus was found to be quite labile. Under some conditions the beat of the heart would increase from 80 to 108 beats a minute.

Minkowski concludes from operative experiments on the fetal nervous system that all of the observed fetal activities are spinal in character. For even after severence of the two cerebral hemispheres all of the observed characteristics persisted.

IV

EXPERIMENTAL DATA

A. NEWBORN KITTENS

In order better to appreciate the full significance of the development of behavior in the embryonic and fetal cats, the writer thinks it advisable to present first a description of one litter of kittens whose behavior was observed shortly after birth.

The kittens were found delivered in the morning. They were still attached to the placenta; the umbilical cord had not yet been severed. The experimenter then severed the cord of each kitten.

When taken away from the mother the kittens cry lustily. They continue to cry as long as they are away from the mother. These cries may be characterized as shrill, piercing cries. As soon as the kittens find the mother the crying ceases and the kittens feed. When the kittens attach themselves to the nipples they hang on with great tenacity. If the mother is lifted into the air the kittens continue to hang on for a few seconds.

At this stage of development the kittens are trembling and shaking. When they make progression movements their heads go to one side and to the other as if searching out one side and the other. Their heads and chests are held off the ground but their bellies are touching the ground. Their rumps are slightly supported by their hind legs. Their posture is not so precarious as it may seem, however, for it is disturbed only by a strong push. Their legs are strong and partly support the weight of their bodies. They also help in maintaining their bodily posture. Their legs are not rigid as is the case in the adult cat in maintaining posture. Their legs are down flat against the ground and slightly off at an angle from the body. Their bodies tremble and their tails are constantly twitching and straightening out as changes in position occur. When the kittens tend to lose their equilibrium their tails straighten out and come up dorsally. Apparently their tails are used as though to help maintain posture. Characteristic positions are assumed by the tail as the kittens move or progress.

When the kitten is stationary and turns it head to the left and then starts to move in that direction the tail curves over to the left. The tail is kept approximately in that position until some change in orientation is brought about. Now when the kitten stops turning and moves in a forward direction the tail comes back from the rump. The tail is raised slightly so long as the kitten progresses in a forward direction. The tail moves to the left or to the right as the head moves to the left or to the right in this forward progression. If, now, the direction of progression is to the right the head comes around to the right and the tail curves around to the right. The tail remains in this position until the direction of orientation is again changed. This behavior is very similar to the corresponding fetal behavior as it was observed in the late fetal stages. Sometimes this observed correlation does not strictly hold.

The leg movements which are involved in progression seem to occur in the following manner. The legs are down flat against the ground and slightly off at an angle from the body. In progression the body is slightly raised off the ground. The body trembles. As the kitten progresses, there are times when definite coordination between the forelegs and the hind legs is observed. This is not always the case, however. Generally the hind legs are thrust out together in a push and then brought up to or toward the belly, producing a hopping effect which resembles the hop of a rabbit. In every case, however, the forelegs are alternately coordinated; first one is thrust out and brought down laterally, the other remaining in a flexed position. Then the other, until then flexed, is thrust out and the previously extended one is flexed, and so on. The leg movements are flat, paddle-like thrusts which come down laterally. The forelegs are much better able to support the body than are the hind legs.

When the kittens are taken away from the mother they cry lustily and vigorously, moving about restlessly. If the mother is prevented from gathering them up an interesting phenomenon is observed. The kittens' orientation to the mother by means of vision is out of the question at this time. Their eyes are not yet open. The kittens may be as near as two inches to the mother and yet her purr, which is definitely audible to the experimenter, is not apparently a directing stimulus in orienting the kittens to the mother. At this time the external auditory meatus is not open.

Finally, there is one source of stimulation which seems to aid the kittens to orient to the mother and eventually to find the nipple. The source of this stimulation seems to be the contact with the mother's fur. Possibly, also, temperature is a contributing factor. So long as the kittens are not in contact with the mother's fur they wander around aimlessly. They come in contact with the mother's fur by what seems to be sheer chance. When this happens a definite change in their behavior occurs. Forward progression takes place and the kittens burrow into the mother's fur, making, at the same time, side-to-side head movements until they find the nipple. Unless it is by chance the kittens do not come in contact with the nipple at once. By making these side-to-side movements they eventually come upon the nipple.

Apparently only cats will bring about behavior such as that noted above. Absorbent cotton was used and the kittens were allowed to come in contact with it. Only definite avoidance responses were elicited. Forward progression or burrowing was not observed. Another female (pregnant) was brought in and the kittens were allowed to come in contact with the fur. Burrowing movements and forward progression were observed. The kittens were next tried with a male cat. Similar responses were observed. An adult white rat was next used. It is doubtful whether the responses which were elicited were of the progression and burrowing type. Apparently, then, only contact with the fur of the cat (possibly temperature also) serves as the effective stimulus in orienting the kittens toward the mother.

When the three kittens were allowed on the towel (used as bottom padding) occasionally they came together. They burrowed into one another and climbed over one another. These newborn kittens are very strong and are able to climb with a fair degree of proficiency. One of them chanced to appoach the mother who was lying on her side. The kitten started to burrow into the fur and then climbed up over the mother making alternate coordinated movements of the forelegs and of the hind legs. It succeeded in climbing the side of the mother only part way and then fell to the floor. [Compare these descriptions with those found in Tilney and Casamajor (66), Langworthy (38), and Windle and Griffin (69).]

B. OBSERVATIONS OF THE EMBRYONIC AND FETAL BEHAVIOR

The following data are compiled from the writer's protocols and from the motion-picture records secured during the course of this investigation.[15] The motion-picture records[16] of the fetal behavior proved to be an invaluable aid and an important adjunct to the writer's observations. Without the motion-picture records, much of the minute and detailed analysis of the observed behavior would have been impossible, consequently masking, to a certain extent, some of the dynamic processes of the developing behavior of the fetus of the cat. For the motion-picture records made it possible, in a modified form, to repeat the experiment as many times as the writer desired by simply projecting again and again the various photographic sequences at any desired developmental stage.

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[15] The writer here wishes to express his indebtedness to Professor Schlosberg of the Department of Psychology for devising the technique and for his assistance in taking the photographic sequences.

[16] About 2500 feet of film were used. From this amount of film the writer selected and edited a 400-foot reel. This reel is accompanied by a descriptive pamphlet and is distributed by the C. J. Stoelting Company, Chicago, Illinois (23).

In the description of the developmental stages which follow only those behavioral characteristics will be described which were observed for the first time at each stage. Unless it is otherwise stated, it will be understood that each successive stage described includes the behavioral reactions which were observed in all the preceding stages.

21-22–Day Stage. There was no observable behavior present at this stage of development. The heart beat was, however, observed through the transparent membrane directly over the heart.

23–Day Stage. An almost imperceptible retraction of the forelegs was possibly observed. This was elicited only when the head, the shoulder, or the paw was stimulated with a camel's-hair brush. Spontaneous behavior was also observed. It consisted of a possible retraction of the forelegs and a barely perceptible bending of the head from left to right. The head movement was definite.

The behavior of the embryos at this stage of development was weak and of short duration. After the embryos were shelled out into the saline bath it was possible to elicit reactions for only about five minutes.

24–Day Stage. Head movements were observed. These consisted of bends to one side. At the same time there were also weak movements of the forelegs.

Stimulating the right shoulder with the brush elicited a slight forward twitch of the right foreleg. There was some doubt as to whether "serpentine" behavior was observed.

25-Day Stage. After the first embryo was shelled out into the saline bath, spontaneous activity occurred. There was a slight bending of the head to one side and a weak flexion of the forelegs. The forelegs moved as units with no observable flexion at the elbow or wrist joints. The trunk moved slightly to the right or left. Active movements of the hind legs were not observed except as they swayed along passively with the rump movement. The embryo was still contained within the amniotic sac.

With the embryo still within the sac, the head, near the right ear, was touched with the brush. The head moved slightly to the left and returned to position again. The forelegs moved as units with no flexion at the wrist or elbow. What appeared to be a wave of muscular contraction passed from the head downward to the rump. The rump turned left or right. The hind legs moved passively as a part of the rump movement.

Stimulating the shoulder, the crown of the head, and the side of the body near the shoulder elicited the same type of behavior just described. However, stimulating from below the shoulder down to the rump elicited no observable behavior.

26-Day Stage. With the fetus in the amniotic sac, the brush was applied behind the right ear. The head turned to the left and returned to position again.

The whole body bowed with a pronounced downward dip of the head. This was followed by a slight extension of the head in an upward movement. The right foreleg flexed slightly, then immediately stretched.

The same fetus was shelled out of the amniotic sac and the brush stimulus was applied to the mid-dorsal region of the back. Body extension was observed. The left foreleg stretched while the right foreleg flexed. There was a weak alternation of extension and flexion in the forelegs. The head twisted to the left and came back to position. The rump swayed to the right slightly.

28–Day Stage. The brush was applied to the left ear. The head rotated weakly from left to right. At the same time the left foreleg flexed weakly. When the brush was applied slightly below the left ear there was a weak extension of the left foreleg followed by a downward lateral movement. There was also a feeble upward movement of the left hind leg toward the head. A weak electrical stimulus was applied to the top of the head near the neck. The head jerked weakly. The head bowed chestward. The left foreleg extended and moved slightly toward the side of the face. When the electrical stimulus was applied to the rump the left foreleg came down laterally toward the rump.

Another fetus was shelled out into the saline bath. It was not removed from the amniotic sac. Behavior was observed with no direct stimulation by the experimenter other than the necessary handling in removing it from the uterus. Weak movements of rotation of the head to the left and to the right were observed; also up-and-down movements of the head. The forelegs moved but without flexion at the wrist or at the elbow.

It was observed in these fetuses that when stimuli were presented in quick succession the responses disappeared. After a short lapse of time response to stimulation reappeared.

29–Day Stage. After the first fetus was shelled out of the uterus and while still contained within the amniotic sac, movements were observed. These consisted of a slight rotation of the head to the left and to the right with a weak paddling or alternate beating of the two forelegs, articulation occurring at the shoulder but not at the elbow or at the wrist. A body twist started at the head and progressed caudad to the rump involving the whole body. As the rump twisted left or right the two hind legs passively moved along with it. This fetus was then delivered out of the amniotic sac into the saline bath and movements in response to experimental stimuli were observed.

The rump was lightly touched with the brush. A roll of the rump and an extension of the hind legs in a slight downward thrust was observed. Simultaneous with these movements of the hind legs a feeble twitch of the tail was also noted. At the same time the body as a whole stretched. The forelegs were extended, coming down laterally toward the rump. The head jerked weakly upward and dorsally. There followed, after these movements, a weak twist in the form of an S, starting at the head and passing continuously caudad to the rump.

The brush was applied to the left shoulder. This elicited a slight lateral flexion of the left foreleg which then relaxed to the starting position.

The brush was passed along the mid-dorsal line of the back as far back as the hind legs at the hips. The body stretched and there was a simultaneous extension of both hind legs in a weak caudal thrust. The forelegs were extended and beat alternately. Then, starting at the head, the S-reaction was observed.

The brush was applied to the right shoulder. The right foreleg was extended and brought down laterally and caudad with articulation occurring at the shoulder only.

The skin was brushed lightly at the side near the left shoulder. This elicited a weak twitch of the skin in a direction toward the rump. Brushing the skin near the middle of the trunk at the side also elicited a weak twitching of the skin. Twitching of the skin could not be elicited when it was stimulated below these points.

The brush was applied to the left side of the face. The head twisted to the right. The two forelegs came up toward the side of the face. The left hind leg flexed slightly and came up toward the side of the body. The body stretched and twisted in the characteristic S-reaction, starting at the head and passing to the rump.

Brushing the left ear elicited the same general type of behavior as when the side of the face was stimulated.

The paws of the legs were stimulated with the brush.

There was no observable response by any paw or any other part of the body.

The crown of the head was stimulated with the brush. The head bowed toward the chest and twisted to the right weakly.

The brush was applied to the mouth. The head twisted to the side, but no movements of the mouth or of the tongue were observed.

The right foreleg was brushed lightly. The only movement observed in response to this stimulation was a forward twitch of both forelegs in a direction toward the head. The stimulus was repeated with the same result.

The brush was applied from just below the right shoulder along the mid-line of the back to a point half way down the back. The body as a whole stiffened. The head jerked ahead and slightly upward dorsally. As the head jerked upward the two forelegs were extended and thrust downward and immediately brought upward toward the face. With this upward movement of the legs the head came down ventrally so that it was between the two forelegs which then relaxed to the normal resting position.

What may be termed a "premature breathing" movement was observed to occur spontaneously. The head dipped toward the chest and was followed by a pronounced contraction near the umbilical cord and by an opening and closing of the mouth. These "premature breathing" movements were also observed to occur upon stimulation of other parts of the body.

In this experiment, unless the fetus was directly stimulated, it remained, for the most part, quiet and motionless.

30–Day Stage. The brush was applied to the left ear of the fetus while it was still contained within the amniotic sac. A wave of movement spread from the head region to the rump in a serpentine, sinuous fashion. The head bowed toward the chest and then came up, rotating to the left and to the right. The two forelegs were thrust out extended and paddled in a weak alternation. The rump twisted and turned to the left and to the right. This rump movement seemed to involve the upper trunk as well as the posterior half of the fetus. The two hind legs came up toward the side slightly. Simultaneous with the twisting movements of the rump the tail twitched weakly. This swaying and twisting of the rump, which involved the upper trunk as well as the rump and the lower trunk, seemed to be a characteristic type of behavior observed at this time.

While the fetus was still in the sac it showed active spontaneous movements. The mouth opened and closed with a protrusion and retraction of the tongue. The left forepaw came up to the mouth with possible flexion at the wrist. The paw came to rest in the mouth but there did not appear to be any sucking movements. The body stretched. The head was raised and was twisted to the left and to the right with both forelegs alternating in paddle-like movements. The rump curved inward toward the belly, the hind legs and tail swaying along with the rump. The right foreleg was brought up to the side of the face with flexion occurring at the elbow and at the wrist.

31–Day Stage. The fetus was still contained within the amniotic sac. Behavior was observed without the direct application of an external stimulus. The behavior of this fetus differed very slightly from that observed in the preceding stage. When the motion-picture records of the two stages were studied it was almost impossible to distinguish the one stage from the other. Except for two items of behavior — back-arching and the C-reaction—the 30- and 31-day stages were practically identical.

"Premature breathing" movements were again observed. The head dipped toward the chest, and the mouth opened. The thorax contracted. The forelegs were thrust out and the hind legs were flexed, coming up toward the forelegs. The back arched dorsally.

The lips of the fetus were touched lightly with the beaded tip of a glass rod. The mouth opened and the lips appeared to purse around the glass tip. Then the mouth closed. These were, possibly, sucking movements.

The first elements of the C-reaction were probably present in the 30-day stage. However, most of the body twisting was of the serpentine type. At this stage the serpentine type of behavior seems to be disappearing and the animal seems almost to coil itself into a bilateral "C." This type of reaction was carefully studied from the motion-picture records both from still frames and from frames in motion. In many cases when the fetus was stimulated the C-reaction was the characteristic type of behavior. One example will describe this type of behavior adequately.

The mid-line of the back just above the rump was lightly brushed. The head jerked upward dorsally. Then the head dipped downward to the chest and twisted to the left. It then unfolded from this twist and began to bend to the left. After the head had started to bend to the left the rump began to follow and bend to the left, the trunk curving at the middle until a "C" was formed, the ends of which were wide. As the head bent over, the forelegs were slightly extended and became flexed when the "C" was formed. The next step in this form of behavior was the reversal to the other side. The head was raised slightly and bent to the opposite side with the forelegs slightly extended. When the head reached the normal position (a position in a straight line with the body) the rump straightened out from the curved position. As this was being done the head bent to the opposite side and was immediately followed by the rump, thus forming another "C" again. This was repeated several times until the fetus came to rest. This C-reaction was smooth and continuous and was bilateral in nature. It was elicited when the fetus was stimulated in almost any part of the body above the rump.

32–Day Stage. "Premature breathing" movements were observed and were carefully analyzed. There was first a contraction of the abdomen at the point where the umbilical cord connects with the fetus. This contraction occurred and the back arched. Then the head dipped ventrally toward the chest. The mouth opened slightly in a gasping manner simultaneous with the umbilical contraction. There was also a slight contraction of the thorax. The head returned upward to the normal resting position, and the back, which, until then, had been arched, straightened out. Sometimes these "premature breathing" movements, starting at the umbilical cord, occurred but also involved the forelegs, which beat alternately in a paddle-like fashion. The trunk twisted and rolled in the characteristic C-reaction. The fetus did not roll or twist so that it came to lay ventral side downward. The hind legs and the posterior part of the fetus did not participate in these reactions.

Upon the application of the stimulus (the brush) these "premature breathing" movements were also elicited in addition to other behavior.

The left foreleg was pinched with a pair of tweezers. Immediately the entire body stretched. The leg pinched was flexed sharply and the opposite leg was extended. The two legs twitched synchronously but weakly. The tail twitched and curved laterally slightly. After the opposite leg stretched the left foreleg stretched so that both forelegs were extended. The head rolled and twisted to the left and was raised slightly laterally left and upward. Then the head came back to the resting position with the forelegs flexing at the elbow.

Upon the application of the stimulus, the "premature breathing" movements described above were elicited.

The left hind leg was pinched with the tweezers. The hind legs twitched simultaneously with a weak extension followed by a slight flexion. As soon as this leg was stimulated there was a sharp lively extension of the upper part of the body. The two forelegs twitched and stretched. The left foreleg was flexed at the elbow and was brought down laterally toward the rump. The right foreleg stretched. The head jerked slightly and twisted to the left and to the right. "Premature breathing" movements were also observed here. In the body extension the back bowed ventrally (caved in).

The side of the body near the hip was pinched with the tweezers. The two hind legs were stretched weakly and synchronously. The tail twitched and straightened out horizontally and returned to a curved position between the two hind legs.

The tail was pinched lightly. The tail straightened out horizontally and then was curved downward and laterally.

When the forelegs were grasped with the tweezers and held there was a weak attempt to "free" the leg which was held. However the opposite leg was not brought over to help in this attempt to "free" the leg which was held with the tweezers.

34–Day Stage. The only new items which were observed at this stage were pinna movements, sucking movements, and a variation of the "freeing" reaction.

When the ears were touched lightly with the brush or when the ears were pinched lightly with the tweezers the pinna was observed to twitch weakly.

The left foreleg was grasped firmly and held with the tweezers. There was a strong pull on the tweezers in an attempt to flex the leg. The right foreleg was vigorously extended. The tail twitched slightly and the hind legs flexed weakly. The opposite forepaw was brought over to the left leg and attempts were made to "free" the leg which was held. The head twisted to the left. When the leg was released from the tweezers the two forelegs were brought up to the side of the face and the head was twisted to the left and raised slightly laterally.

The brush was placed at the tip of the mouth. At first there were definite attempts at sucking which were followed by avoidance movements of the head away from the stimulus. The two forepaws were brought up to the mouth and pushed or pawed at the brush. The head then twisted and turned away from the brush.

36–Day Stage. The left foreleg was lightly stroked with the brush. The left leg was immediately flexed and was then returned to the normal resting position. No other part of the body was involved in this movement. It was a simple and isolated movement of the foreleg alone. When the forelegs were brushed more strongly the resulting behavior was distinctly different. The left fore-leg kicked out sharply and the toes of the foreleg were observed to spread. The opposite or right foreleg was flexed and pulled to one side. Then the two forelegs were extended and brought up and over the sides of the face. The forelegs then beat alternately. The two hind legs were flexed slightly and then kicked out sharply. As the hind legs were flexed, the tail curved along with them. When the hind legs kicked out, the tail, which until then was curved, straightened out horizontally. The tail then returned to the curved position as the legs returned to the normal resting position.

The base of the ear was slightly brushed. There was no observable response made to this stimulation. It was tried again later. This time a response occurred which might be interpreted as the beginnings of the scratch reaction. The left hind leg was flexed sharply and was brought up to the side but without touching it. This flexion was the only thing observed and it was not repeated. It was also observed that the flexion of the hind leg involved flexion at the knee.

These fetuses were delivered into the air also. After the observations had been completed the umbilical cord was ligated and severed. The fetuses were delivered onto an electric heating pad. The pulsations of the heart could be seen with the naked eye. The fetuses did not start and maintain respiration. Several gasping and convulsive attempts to breathe were made which were similar in character to the "premature breathing" movements of the fetuses when they were in the physiological salt solution. The strength and amount of response of these fetuses began to die down and as time passed they became less and less active until it was impossible to elicit any movements even with the strongest stimulation. This loss of activity could not have been due to lack of heat because that element had been provided. At this stage the skin began to dry and shrink. But one of the fetuses was held in the experimenter's hand and its body was immersed in the physiological salt solution, care being taken to keep its mouth and nose above the solution. Under these circumstances the same gradual loss of activity was observed. After approximately 20 minutes the heart ceased to beat also. If respiration in a regular and continuous manner cannot be set up in these fetuses at this stage then the gradual loss of activity must be attributed to this fact.

38–Day Stage. The fetus was lying on its right side. The left foreleg was pinched with the tweezers. The left foreleg was flexed sharply. The right foreleg was thrust out straight from the body sharply and vigorously. At the same time the head was jerked upward and dorsally and slightly to the right. The whole body stiffened with a jerk. The two hind legs were thrust out away from the rump, while the tail, which, until then, was curved under and between the hind legs, was straightened out and was curved slightly dorsally. After the flexion and extension of the forelegs there occurred alternate paddling movements of the forelegs, together with a twisting and turning of the head. Then the hind limbs were flexed and the tail came back to the partially curved position. The body of the fetus as a whole relaxed.

The left hind leg was pinched with the tweezers. The left hind leg was flexed sharply with flexion occurring at the ankle and at the shoulder. The right hind leg was extended and was thrust out sharply and vigorously. Then the left hind leg was extended so that the two hind legs were extended. The tail twitched and straightened out, curving dorsally slightly. The whole body of the fetus stretched and stiffened with one pulling movement in such a manner that the fetus was pulled forward. The back caved in and the head was jerked outward and upward dorsally, simultaneous with the stretching of the body. The head rolled slightly to the right and then back to position again. The two forelegs were first thrust out sharply and before complete extension was attained were pulled down in a stiff paddle-like fashion laterally and toward the hind legs. The mouth opened and closed and contractions were observed at the thorax but more predominantly at the abdomen near the umbilical cord.

In the stimulation of both the fore- and the hind legs there were alternate paddling thrusts and flexions of the fore- and the hind legs. These movements were somewhat more precise and sharp in the forelegs than in the hind legs. In the forelegs there appeared to be a fair degree of coordination in the paddling movements, whereas the hind legs lacked this degree of coordination. The hind legs more often worked synchronously than in alternation. *In no case* were these movements of the fore- and of the hind legs observed so that the fore- and the hind legs were *coordinated as in walking,* i.e., left fore-, right hind, and right fore-, left hind.

The left ear was brushed. The pinna twitched. The body as a whole stiffened with a jerk, the back caving in. The head twisted to the left. The two forelegs were thrust out sharply and were then flexed. As the head twisted to the left, the right foreleg which was flexed was brought over to the neck under the chin. The left foreleg was brought over to the side of the face between the eye and the mouth. The hind legs kicked out. The tail straightened out and curved slightly dorsally. When the left foreleg was brought over to the side of the face, the squirmings and twistings of the fetus brought it about that the left foreleg came in contact with the mouth which was opening and closing. When the forelegs came in contact with the mouth the tongue pursed around the left foreleg, the mouth closed, and apparent sucking or biting movements resulted. The left foreleg was then released and the right foreleg was then brought over to the mouth and the biting or sucking movements occurred again. In the meantime, the leg which was not in the mouth was extended and the fetus stretched and squirmed. Spontaneous twitchings of the pinna were also observed to occur.

The scratch reaction (or the rudiments of the scratch reaction) was elicited. When the ear, the nose, the mouth, the sides of the face, and the sides of the body were brushed the hind leg on the same side was flexed and brought up toward the spot stimulated, executing several thrusting beats.

When the brush was lightly applied to the forepaw a flexion of that leg alone occurred. If the stimulation was more intense, however, diffuse and massive movements of the body resulted.

The movements which have been described and which were elicited by the application of a definite stimulus were also observed to occur spontaneously, i.e., the stimulus for these movements was not known or was not externally present. A description of one case will give a general idea of the type of behavior which was observed.

The fetus was lying on its side. The body of the fetus as a whole jerked and stiffened. The back caved in and the head jerked upward and dorsally. The two hind legs kicked out while at the same time the tail straightened out and curved slightly dorsally. The two forelegs were extended vigorously and paddled alternately but never in coordination with the paddlings of the hind legs. The fetus twisted at the shoulder left and right while the rest of the trunk swayed to the right and to the left but did not twist. Then the fetus turned and twisted over so that the anterior portion (shoulder upward) was dorsal side up, head down, and forelegs flexed under up at the breast. The rest of the body twisted over so that the whole fetus was dorsal side up toward the experimenter who was viewing from above. In this position the forelegs and the hind legs beat alternately but not in coordination. Then the fetus rolled onto its side again with twisting, squirming, and rotation movements of the trunk, and with stretching of the legs, body, and head. The mouth opened and closed and contractions occurred at the thorax and at the abdomen. The pinna was observed to twitch. In some cases where spontaneous movements were observed to occur the forelegs of the fetus came in contact with the mouth and the sucking, biting behavior described above was again observed.

The spontaneous behavior was not always as massive and as diffuse as in the case described. In some cases the spontaneous behavior amounted only to twitchings or slight movements of the head, the forelegs, the hind legs, or the tail.

40–Day Stage. The upper (dorsal) side of the left forepaw was lightly brushed. The paw was extended at the wrist, snapping up toward the stimulus. This movement was confined to the wrist only. The lower side of the forepaw (the toe pads) was also lightly brushed. The paw flexed at the wrist and snapped in the direction of the stimulus, coming toward the belly.

The brush was applied to the left hind leg. The leg was flexed slightly. No other part of the body was involved. This was an individualized movement of the hind leg alone.

The vibrissae were lightly touched with the camel's-hair brush. There was a twitching of the underlying musculature which made the vibrissae move.

Stimulating lightly with the brush any part of the lateral skin surface between the shoulders and the rump elicited a twitching of the skin. This twitching of the skin had its source at the fold of the skin between the thigh and the side of the body. The twitching extended downward at an angle and toward the head. No matter where the fetus was touched with the brush on the side of the body this skin-twitching was elicited. When, however, the mid-dorsal line of the back was brushed the skin-twitching was not elicited. When the shoulder, the neck, or the legs were brushed the skin-twitching was not elicited. The farther away the stimulus was from the source of the skin-twitch, the less vigorous the twitch which was elicited; the nearer the stimulus was to the source of the twitch, the more vigorous the twitch elicited. Stimulation of the ventral skin surface did not elicit the skin-twitching.

When the skin surface between the shoulder and the side was lightly brushed movements corresponding to those just described were observed. The most vigorous skin twitching was observed when this spot was brushed. The direction of the twitch was downward at an angle and toward the rump. As the distance of the stimulation from the original spot was increased the skin-twitching was less vigorous.

43-Day Stage. The fetus was lying on its right side. The corner of the fetus' mouth was lightly touched with the beaded tip of a glass rod. The lower jaw dropped sharply. The tongue was thrust out. The tongue was then retracted and the mouth was closed. The head was also observed to jerk and to bend sharply to the right. This stimulus was applied several times. The jaw and the tongue movements were always observed. Other bodily components were observed to occur along with the stimulation but they were variable in their appearance. Sometimes the head, the forelegs, or the hind legs were observed to move at one time. Sometimes, too, the bodily movements were weak, sometimes they were more vigorous in their appearance.

The upper lip was brushed lightly. The lip curled upward and outward very weakly. The upper lip was also lightly touched with the beaded tip of a glass rod. The lip curled upward and outward.

The beaded tip of a glass rod was placed between the two lips and into the mouth. The two lips closed around the glass rod and movement of the neck muscles was observed. These were not swallowing reactions, however. The head was extended as if to hold on to the glass tip for a longer time. When the rod was taken away from the mouth the lower jaw dropped and the tongue was thrust out. These were certainly sucking movements with a hint of the rudimentary appearance of swallowing reactions.

An attempt was made to elicit the so-called "deep neck reactions" of Magnus. These reactions are elicited by a change of position of the head when the position of the trunk is maintained unchanged. The head may be twisted, bent, or raised and lowered. The results which were observed follow.

1. The head was twisted to the left. The left foreleg was extended; the right foreleg was flexed.
2. The head was twisted to the right. The right foreleg was extended; the left foreleg was flexed.
3. The head was bent to the left. The left foreleg was extended; the right foreleg was flexed.
4. The head was bent to the right. The right foreleg was extended; the left foreleg was flexed.
5. The head was raised. Both forelegs were simultaneously extended.
6. The head was lowered. Both forelegs were simultaneously flexed.

In these reactions the hind legs remained in a partially flexed position.

When the head of the fetus was grasped (in order to elicit these reactions) between the experimenter's forefinger and thumb, the fetus attempted to "free" itself. The two forelegs were brought up over the sides of the head. An opening and closing of the mouth was also observed. Thus the "deep neck reactions" tend to be masked by these "freeing" movements. However, after the head is maintained in the proper position for a time, the "freeing" reactions disappear and the "deep neck reactions" appear.

45-Day Stage. In general, the same type of reactions were elicited, in so far as the experimenter observed them, as in the 43-day stage.

46-Day Stage. The outer (dorsal) side of the left hind paw was lightly brushed. A sharp, quick flexion of the hind legs toward the rump was observed. At the same time the toes were observed to spread or fan widely. The hind legs then returned to a passively flexed position.

The closed eyelid was lightly touched with the beaded tip of a glass rod. Contraction of the closed eyelid was observed. The eyelid was also brushed. Contraction of the closed eyelid was noted. These were individualized responses which involved no other part of the body.

From the experimenter's observations with the camel's-hair brush as a stimulus, *reactions were elicited* from certain regions only. These were unmistakable and definite. After continued stimulation, however, the stimulated spot appeared to become "fatigued," for when the stimulation was discontinued and the stimulus was applied again, after a short interval of time, the reaction was again elicited.

Spontaneous "premature breathing" movements were observed to be occurring frequently but not in any definite rhythm or at any definite frequency. Stimulation of the fetus also elicited these movements.

These fetuses were delivered into the air on an electric heating pad. The heart was observed to beat but with a continuously lowered frequency until the animals died. The reactions were sluggish and weak. They were not similar to the reactions of the fetuses observed in the physiological salt solution.

Continuous, rhythmic breathing was not set up. When the fetuses were first delivered into the air several gasping movements were observed. These movements consisted of a vigorous contraction of the thorax and abdomen.

47–Day Stage. This stage was similar, in the observed reactions, to the 46–day stage.

49–Day Stage. At this stage of development the "premature breathing" movements of the fetuses in the physiological salt solution were again observed. They differed in no essential way from those already described for the other stages in which they were observed.

Fetuses from two litters were delivered into the air on an electric heating pad. The fetuses of the first litter set up continuous and rhythmic breathing in the air. One fetus lived in the air for two and one-half hours.

Five fetuses from another litter were delivered into the air. At 6:10 P.M. the first fetus was delivered into the air. At 7:30 P.M. the second fetus was delivered. At 9 P.M. two more fetuses were delivered. The last one was delivered at 11 P.M. They were all alive at 12:30 A.M., when the experimenter left the laboratory. When the experimenter returned to the laboratory at 9:00 the next morning all five fetuses were found dead.

The fetuses delivered into the air were more sluggish and less vigorous in their reactions than when they were observed in the physiological salt solution. The fetuses remained, for the most part, on their sides and inactive. Very few spontaneous reactions were observed. There were twitchings of the body as a whole. Twitchings and thrusts of the forelegs and hind legs and rolling of the body were also observed. Attempts were also made to right themselves. In these attempts the reactions were vigorous. The forelegs beat in a well-coordinated manner with sweeping movements at the side and thrusts out and downward laterally. The hind-leg reactions were likewise vigorous but they were also not as well coordinated as in the forelegs. In no case were the forelegs and the hind legs coordinated as in walking.

When the fetus was taken from the physiological salt solution and delivered into the air breathing movements were not set up at once. Opening and closing of the mouth was observed (gasping). Contraction of the thorax and of the abdominal musculature, together with a dipping of the head chestward, were observed. Vigorous stimulation either by handling or by strong pinching with the tweezers seemed to be necessary in order to set the breathing mechanism in action. After such vigorous stimulation a gasping, convulsive breathing was set up. As time passed the convulsive gasps became stronger. There was a vigorous contraction of the abdomen at the umbilical cord. The back arched slightly, the head coming down chestward. The mouth opened and closed. The tongue was thrust out. A hissing noise was heard as the fetus inspired air. A continuous, regular, rhythmic breathing was not set up during the course of the observations.

Righting reactions were observed in the physiological salt solution. These righting reactions were observed when the forelegs or the hind legs were stimulated with the tweezers. The fetus twisted the anterior half of its body so that it came to lie dorsal side up, while the posterior half of the body remained on its side. At this stage the fetus assumed this position often, in contrast with the earlier stages where the fetuses always assumed a position on their sides.

The reactions at this stage were much more precise, more individualized, less diffuse, and less massive. When weak stimuli (the brush, the tweezers, or the glass tip) were applied, the reactions were quick, sharp, nicely coordinated and individualized. If the stimuli were strong the massive, diffuse, irradiated reactions were observed. A few examples will serve to illustrate this point.

The beaded tip of a glass rod was applied to the base of the left ear. The left hind leg was not brought up in a scratch reaction as in the earlier stages. The head only was shaken, much as a dog shakes its head after it has been wet. Again, when the left forepaw was lightly touched with the brush or with the glass rod both forelegs were flexed at the wrist and, with articulation at the shoulder, were brought to the sides of the body almost up to the mid-dorsal line of the back.

51–Day Stage. Rolling over onto the back, swallowing, and vocalization were the new reactions observed on this day.

In the physiological salt solution the fetuses were observed to roll the body so that it was almost ventral side up. This was elicited only with a strong stimulus (tweezers). The head came around to the left. The shoulders turned and the forelegs came along with them. The roll then spread caudad until the entire body was rolled over onto the back.

After the fetuses had been delivered into the air attempts were made to elicit swallowing reactions. A medicine dropper filled with water was placed into the mouth of the fetus. The lips closed around the tip of the dropper and sucking movements began. Muscular movements of the throat were also observed. The water in the medicine dropper was sucked and swallowed.

Vocalization was observed when the fetuses had been delivered into the air.

53–Day Stage. Urination, excretion, and crawling were observed at this stage.

The crawling reactions were similar to the descriptions given of the newborn kittens, except that in the case of the 53–day fetuses the rump and hind legs were not as strong. These fetuses have great difficulty in maintaining an upright posture of the rump.

55– and 58–Day Stages. No new items of behavior were observed at these stages.

V

DISCUSSION OF RESULTS AND CONCLUSIONS

In the preceding section the experimental data of the embryonic and fetal reactions was necessarily presented in a brief concise form. The results, as they stand, indicate certain general tendencies in the developing reactions of the fetus of the cat. However, when a developmental chart of the various fetal reactions is plotted, some very definite developmental relations appear. Figure 6 illustrates such a developmental chart. The "fertilization" age is plotted on the abscissa. On the ordinate are plotted the various reactions as they were observed at each day investigated.

Movement other than the heart beat was first observed in embryos 23 days old. Before this time the embryos were non-motile. The movements observed on the 23rd day consisted of a unilateral head-bending and a passive movement of the forelegs. Foreleg flexion and unilateral trunk-bending were also thought to have been observed. But these movements, if they were observed, were so slight and of such short duration that it is distinctly open to question whether they occurred at all. On the 24th day, active foreleg flexion and foreleg extension were definitely observed. Unilateral trunk-bending was also definitely observed at this time with a hint of "serpentine" twisting (see page 337 of this paper). On the 25th day three new reactions were observed in addition to those occurring on the previous days. These were a bilateral trunk-bending, a uni-

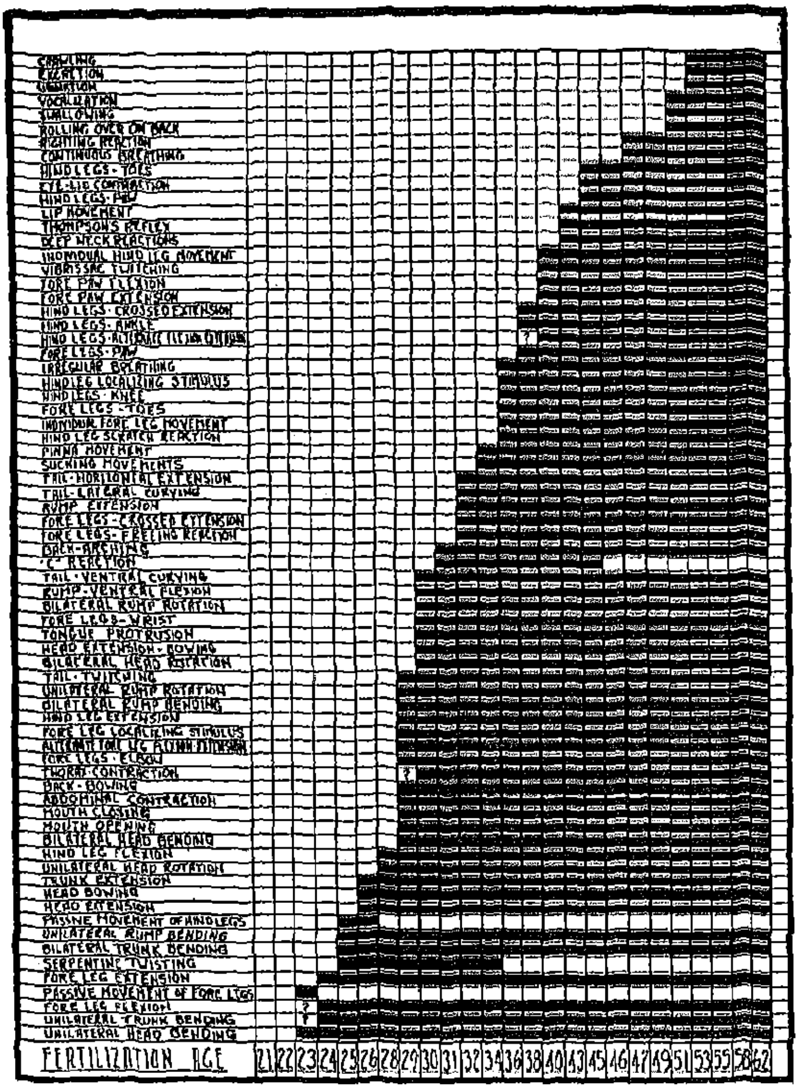

FIGURE 6

A CHART CONSTRUCTED TO SHOW THE DEVELOPMENT OF BEHAVIOR IN CAT FETUSES OF VARIOUS GESTATION AGES lateral rump-bending, and a passive movement of the hind legs. At this time definite "serpentine" twisting was observed. Now, as the gestation age increases, there is a rapid, progressive, and continuous development of behavior from the simple movements of the early stages to the more complicated behavior observed in the young kitten a few hours after birth.

Such a developmental chart, while illustrating the continuous, progressive development of behavior, tends, however, to mask the fact that certain qualitative changes are taking place. In the early stages the behavior is diffuse, variable, relatively uncoordinated, and weak. With the increase in gestation age, the reactions become more vigorous, more regular in their appearance, less variable, individualized, and better coordinated. These qualitative changes do not occur abruptly but are continuously progressive modifications in the *quality of the observed reactions.* Moreover, these qualitative changes do not, as it were, "invade" the total organism at once. Rather they seem to follow a general course in their development beginning at the head region and progressing toward the tail.

For purposes of further analysis the body of the cat may arbitrarily be divided into six parts: head, forelegs, trunk, hind legs, rump, and tail. If we follow out the appearance of the first movement in each arbitrary segment in relation to the increase in gestation age, a definite development trend is noticeable (Figure 7). The first movement of the head is a unilateral bending and appears on the 23rd day. On the 24th day foreleg flexion, foreleg extension, and unilateral

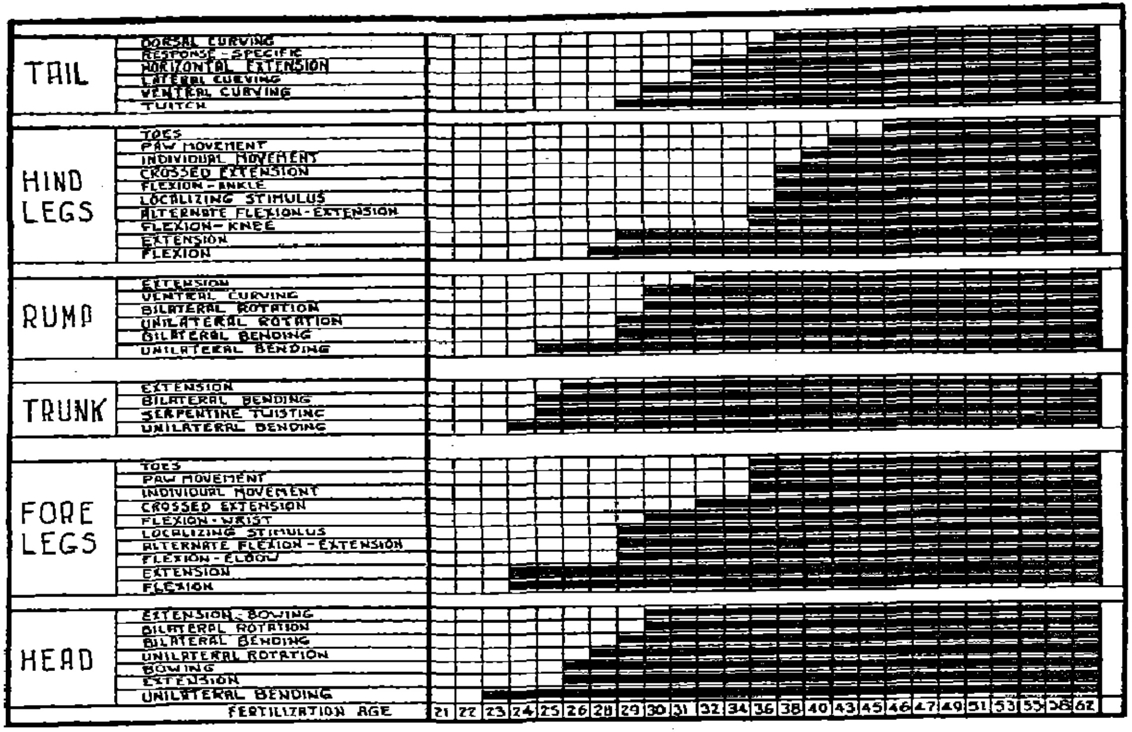

FIGURE 7

A CHART TO SHOW THE DEVELOPMENT OF BEHAVIOR IN CAT FETUSES OF VARIOUS AGES, CEPHALOCAUDAL DEVELOPMENT, AND THE INDIVIDUATION OF BEHAVIOR IN SPECIAL BODY AREAS trunk-bending are observed. Unilateral rump-bending appears on the 25th day. Hind-leg flexion is present on the 28th day, and on the 29th day twitching of the tail is observed to be present. Thus, in analyzing the simple movements of these gross divisions of the body of the fetus, the developmental trend seems to be progressing from the head region toward the tail, i.e., it is anteroposterior or cephalocaudal in direction.

A more detailed analysis of the data will, perhaps, make this point more clear. A cursory inspection of the developmental chart (Figure 7) reveals the fact that the movements of the head region are continuously developing in advance of the caudal segments. Each segment in turn is, in its simple movements, developing in advance of the segment posterior to it, except, perhaps, for the trunk region.

A further analysis of the development of the movements of the forelegs in comparison with the development of the movements of the hind legs demonstrates this point more vividly. If each movement in the forelegs is compared in turn with the same movement in the hind legs and both of these plotted against increase in gestation age we find that functionally the forelegs develop in advance of the hind legs (Figure 7).

1. Foreleg flexion and extension with articulation at the shoulder appear on the 24th day. Hind-leg flexion with articulation at the hip is present at the 28th day. Hind-leg extension with articulation at the hip appears on the 29th day.
2. Foreleg flexion at the elbow appears on the 29th

day, while hind-leg flexion at the knee is present on the 36th day.

3. Alternate flexion-extension appears in the forelegs on the 29th day and in the hind legs on the 36th day.
4. The forelegs' localizing the stimulus, i.e., the legs' tending to come toward the spot stimulated, appears on the 29th day, while in the hind legs it is present on the 36th day.
5. Foreleg flexion at the wrist appears on the 30th day, and hind-leg flexion at the ankle is present at the 38th day.
6. Crossed extension of the forelegs is present on the 32nd day. In the hind legs it appears on the 38th day.
7. Individual movement of the forelegs appears on the 36th day. Individual movement of the hind legs is present on the 40th day.
8. Paw movements in the forelegs are present on the 36th day. Paw movements in the hind legs are observed on the 43rd day.
9. Movements of the toes of the forelegs appear on the 36th day. Movements of the toes of the hind legs are present on the 46th day.

A further inspection of the data in the development of behavior in the fore- and hind legs reveals still another aspect of growth. The development of behavior begins with the simple flexion and extension of the foreleg or of the hind leg as a whole, with articulation occurring at the shoulder or at the hip. With the increase in gestation age the movements appear first in the proximal regions and in the distal regions later, passing from shoulder or hip articulation to movements at the toes.

The development of cutaneous sensitivity to punctiform stimulation was not systematically investigated (57). In some cases punctiform stimulation was used. For the most part, however, areal stimulation was used (camel's-hair brush) and in some cases a pressure stimulus (tweezers) was used. However, some general statements concerning the development of cutaneous sensitivity may be made at this time.

In the earliest stages of embryonic development cutaneous stimulation leads, largely, to a movement of the forelegs, of the head, trunk, or rump. Later, however, such stimulation leads to a twitching of the skin.

For example, a weak twitch of the skin in a direction toward the rump to a light brushing was observed for the first time on the 29th day. On the 40th day lightly touching the vibrissae with the brush elicited a twitch of the underlying musculature which made the vibrissae move. Skin-twitches were very definitely observed and described in detail on the 40th day (see pages 352-354 of this paper). The direction of development of such skin sensitivity is undoubtedly cephalocaudal.

Along with the development of such skin sensitivity the development of what may be termed reflexogenous zones may be remarked. In the earliest stages of motility, when various parts of the body of the fetus are stimulated, and in accordance with the development of sensitivity in a cephalocaudal direction, such stimulation elicits diffuse, variable, uncoordinated, and very "random" responses. To the experimenter there is apparently no connection between the place of application of the stimulus, the resulting response, and the "appropriateness" of such a response. Stimulation of the fetus at such times is, apparently, just as likely, within the limits of its sensitivity and the degree of development, to lead to one bit of behavior as it is to another. In many cases, especially with the very young fetuses, a uniform pattern of behavior is observed whether the fetus is stimulated on the snout, the head, the shoulders, the trunk, or even if no external stimulus is applied by the experimenter (spontaneous behavior). In other words, the writer found it extremely difficult to differentiate one pattern of behavior from another even though different parts of the body of the fetus were stimulated. Further, in the earliest stages of development a rather vigorous form of stimulation is required to elicit behavior where a weak stimulus (light touch) would not be at all adequate. In these earliest stages, then, any "spot" or, rather, part of the body within a rather large area would serve to elicit these variable, diffuse, sometimes similar, uncoordinated patterns of behavior to somewhat vigorous stimulation.

As behavior development continues, however, a continuously progressive change may be observed in the refinement and discreteness of response in the fetus, together with an increase in sensitivity to stimulation, i.e., a weak stimulus now becomes adequate for response where formerly such stimulation was inadequate. For example, in the earliest stages, when the foreleg was somewhat vigorously stimulated, movements of the mouth, tongue, pinna, closed eyelid, head, trunk, rump, and possibly the hind legs followed. Such behavior was elicited no matter what part of the leg was stimulated. However, a stage is reached in the behavior development of the fetus where the lightest touch when applied to the dorsal side of the forepaw, for example, leads to an extension of the paw alone, such behavior being rather uniformly and discretely elicited. The uniformity and discreteness of response are, of course, functions of the level of development at any particular time. The other responses which seemed to the experimenter to make that behavior pattern so "inappropriate" (movements of the tongue, eyelid, etc.) have dropped out of this particular pattern of behavior. Furthermore, a particular part of the leg, the dorsal side of the paw, must be stimulated in order to elicit such behavior, for when the volar side of the paw was stimulated a flexion of the paw with a slight cupping of the toes was observed.

As a further illustration of this point the following may be noted. In a 31-day fetus the C-reaction was smooth and continuous and was bilateral in nature. It was elicited when the fetus was stimulated in almost any part of the body above the rump (see page 344 of this paper). Contrast this, now, with the following observations of a 36-day fetus. The left foreleg was lightly stroked with the brush. The left foreleg was immediately flexed and was then returned to the normal resting position. No other part of the body was involved. It was a simple and isolated movement of the foreleg alone (see page 347 of this paper; also pages 351 and 352-353, and especially the second paragraph of page 354).

In outline, then, we have followed a continuous and progressive development of the sensitivity of reflexogenous zones. Such a development of the sensitivity of reflexogenous zones has passed through a continuous and transitional development from a time when rather vigorous stimulation of any part ("spot") of the body within a rather large area serves to elicit variable, diffuse, massive, sometimes similar, uncoordinated patterns of behavior to a later time[17] when a lighter stimulus becomes adequate, within a much more circumscribed, and more or less specific area, for precise, well-coordinated, uniform, and less variable, and more "appropriate" patterns of behavior. Furthermore, the direction of such a development is undoubtedly cephalocaudal.[18] [19]

Long before the fetus of the cat has, in its prenatal environment, any need[20] of a recepto-neuro-muscular mechanism for air-breathing, certain movements appear. From the genetic point of view such movements are the behavioral antecedents of a breathing mechanism which normally becomes functional at the birth of the organism.

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[17] Again the writer finds it necessary to repeat that the appearance of behavior in any of its manifestations is a function of the particular level of development, behavioral and biological, at any particular stage.

[18] E. B. Holt (31) offers a physiological theory of the "education of sensory surfaces."

[19] L. Carmichael and the present writer have completed an investigation of the development of behavior in the fetal guinea pig. L. Carmichael is interested in making a detailed examination of the development of reflexogenous zones. The present writer is interested in the more general aspects of behavior development in the fetal guinea pig (16, 22).

[20] By the use of this word the writer implies nothing of a teleological nature.

Perhaps the first antecedents of air-breathing consist of movements of the lower jaw and tongue which are described as mouth movements, and of abdominal and thoracic contractions. The first mouth movements were observed on the 29th day of development. Abdominal contractions were also observed on this day. Thoracic contractions and tongue movements were observed for the first time on the 30th day. The pattern of these movements was termed "premature breathing" and was first noted on the 29th day. These "premature breathing" movements were observed to occur spontaneously as well as upon direct stimulation. Fetuses of a 36-day litter were delivered into the air onto an electric heating pad. Respiration was not begun. Several gasping and convulsive attempts to breathe were made which were similar in character to the "premature breathing" movements of the fetuses observed in the salt solution. At this time the breathing mechanism (in a behavioral and physiological sense) is not yet ready to function.

As late as the 47th day of the gestation period, fetuses, when delivered into the air, were not able to set up a continuous, rhythmic breathing (see page 357 of this paper). On the 49th day of development, however, breathing, although spasmodic, was set up in five fetuses. In another litter one fetus breathed regularly and rhythmically for three hours, another for two and one-half hours. If reference is made to the observations of the activities of the fetuses when delivered into the air (pages 357 ff. of this paper) the similarity of these movements to the movements made by younger fetuses may be noted.

By the 53rd day, however, fetuses delivered into the air succeed in setting up and continuing a regular and rhythmic breathing. The writer succeeded in keeping one animal alive for two days. In these animals, as well as in the older fetuses, the head, mouth, and tongue movements, and, in general, the convulsive type of movements disappear. In their stead a regular and rhythmic breathing is set up.

The activity of breathing, then, which is observed in a newborn kitten is the product of a long and genetically continuous course of prenatal development.

From the genetic point of view it will be interesting, now, to trace the development of locomotion in the fetus of the cat. Locomotion involves not only the execution of leg movements but includes the development of posture and of righting as well. Locomotion in the cat depends primarily upon the development of the sensitivity of the exteroceptors and proprioceptors with a subsequent organization of the necessary parts of the body into a behavior pattern of locomotion. This implies the development of postural reactions of the head and trunk, together with the development of a nicely timed rhythm of movement between the fore- and hind legs. Walking, trotting, or running consists, in a narrow sense, of a rhythmic coordination between the fore- and the hind legs such that, for example, the left fore-

and right hind legs are synchronized in their movements while the right fore- and the left hind legs are oppositely synchronized in their movements. However, until at least postural reactions of the head, trunk, and rump are fairly well developed, locomotion, as such, cannot be effected.

If the developmental chart (Figure 7) is studied, the course of the development of locomotion may be made out. In the very earliest stages the embryo usually rests on one side or the other. It is not until rather late in the gestation period (about the 38th day, see page 352 of this paper) that the fetus comes to have at least the anterior end of the body dorsal side up. It has also, by this time, well-developed postural reactions of the head. The movements of the forelegs are especially well developed, while the development of the hind legs still lags behind that of the forelegs.

The earliest movements of the cat embryo consist of a unilateral head-bending, unilateral trunk-bending, and a flexion and extension of the forelegs as a whole. It is important that the development of movement in each of the parts of the body involved in locomotion be followed through the course of the gestation period.[21]

The movements of the head pass progressively through the stages of (1) head extension; (2) head-bowing; (3) unilateral head-rotation; (4) bilateral head-bending; (5) bilateral head-rotation; (6) head extension-bowing.

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[21] It must be remembered that all three phases of the development of locomotion are progressing synchronously even though separate items in each phase have a different rate of development. The various behavior patterns are differently organized at the separate stages of development.

The movements of the trunk and rump pass through the following stages of progressive development: (1) unilateral trunk-bending; (2) "serpentine" twisting of the trunk; (3) bilateral trunk-bending; (4) unilateral rump-bending; (5) trunk extension; (6) bilateral rump-bending; (7) unilateral rump-rotation; (8) bilateral rump-rotation; (9) rump—ventral flexion; (10) C-reaction; (11) rump extension; and (12) deep neck reactions.

The forelegs and the hind legs pass through like phases of development but the hind legs lag behind the forelegs in their rate of development. They pass, in their development, through the following stages: (1) flexion; (2) extension; (3) flexion—elbow (knee); (4) alternate flexion-extension; (5) flexion—wrist (ankle); (6) crossed extension; (7) individual movement; (8) paw movement; and (9) toe movement.

Locomotion seems to consist of an organization of head, trunk, rump, and fore- and hind-leg movements in time. Locomotion develops from the "primitive" serpentine behavior observed in the embryo, passing through the C-reaction to righting and crawling.

As far as the leg development of the fetus is concerned, it has been previously stated that development begins in the forelegs first and in the hind legs later. The development of the forelegs progresses in advance of the development in the hind legs. In the early stages of prenatal development alternate rhythmic paddling movements of the forelegs may be observed. Such movements come to involve the entire limb with articulation at all the joints and, later, at any joint in a local response. Much later the hind legs reach a similar stage of development. It is only in the last few days of the gestation period that occasionally all four legs beat in the walking rhythm, the hind legs eventually dropping out of phase with the forelegs. Even in the newborn kitten locomotion consists chiefly of strong *foreleg thrusts out from the sides of the body in paddle*-like movements. The hind legs are flexed or extended together and only occasionally do they fall into the synchronized rhythm of walking. The extreme caudal end of the kitten, especially the hind legs, is often dragged along (see pages 332 f. of this paper).[22]

The feeding reaction passes successively through the development of tongue movements, mouth movements of opening and closing, sucking, and swallowing (ingestion) to the feeding reactions of the newborn kitten.[23]

While what may be designated as the "wave of development" seems to be passing from head to tail, involving the gross musculature, still further development is taking place involving the finer musculature of the body.

If we refer to the data (Figure 6) we find that a series of other movements are appearing at the same time and not independently of the movements which have been described above. On the 29th day the mouth opens and closes. On the 30th day tongue protrusion appears. Sucking and pinna movements are present on the 34th day. Irregular breathing movements in air first appear on the 36th day. On the 40th day the vibrissae move for the first time. Deep neck reactions, Thompson's reflex (mouth, lip, and tongue movements which are elicited when the corner of the mouth is stimulated), appear on the 43rd day. Closed eyelid contraction is present on the 46th day. Continuous breathing in air is present on the 49th day. Swallowing and vocalization appear on the 51st day. Urination, excretion, and crawling are present on the 53rd day.

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[22] It is interesting here to notice the general similarity of the development of locomotion in Amblystoma and in the cat (18).

[23] Lincoln (43), working in the Brown Psychological Laboratory, has made a detailed investigation of the development of the feeding reaction in the albino-rat fetus. Angulo y González (7) has carried out a similar investigation.

The picture of the newborn kitten presents, essentially, an organism which is able to walk (although still in somewhat of a crawl), to feed, to maintain an upright posture, to find warmth and the source of food, and to breathe. It has developed a certain degree of sensitivity, although the auditory and the visual functions have yet to appear. The newborn kitten is somewhat of a "helpless" creature in coping with its postnatal environment, yet it has the necessary equipment for a certain type of biological adaptation. And we have seen that this equipment, such as it is, is the product of a long, continuous, and progressive course of prenatal development.

On the basis of the results of the present investigation it is not maintained that the separate reactions which have been described appear on a definite, specified day in the course of development in all normal cat embryos and fetuses. Rather the emphasis is to be placed upon the developmental relations which exist among the various items. In some cases, as it has been previously stated, in the present experiment the intervals of the gestation age between observations were two or more days. This would preclude any possibility of definitely asserting that a certain item of behavior appears on a given day of the gestation period.

It is also realized that the number of animals used in this experiment was small. Further experiments with a larger number of animals in which the fetal reactions will be observed at shorter intervals of gestation age are anticipated. With these qualifications, it is, perhaps, justifiable to make the following tentative conclusions.

1. Before birth there is a rapid, progressive, and continuous development of behavior in the fetus of the cat.

2. The development of behavior progresses from a diffuse, massive, variable, relatively unorganized state to a condition where many of the reactions are more regular in their appearance, less variable, better organized, and relatively individualized.

3. In the early stages of prenatal development the behavior appears to be progressing along a cephalocaudal course.

4. The development of the sensitivity of the reflexogenous zones passes through a continuous and transitional development from a time when rather vigorous stimulation of any "spot" of the body within a large area serves to elicit variable, diffuse, uncoordinated patterns of behavior to a later time when a weak stim-

ulus becomes adequate, within a much more circumscribed area, for precise, well-coordinated, uniform, and less variable patterns of behavior. The direction of such development is cephalocaudal.

5. The "primitive" reactions of breathing, righting, locomotion, and feeding are the products of a long and continuously progressive course of prenatal development.

6. Behavior development appears first in the gross musculature, and in the fine musculature later.

7. Behavior develops in each of the limbs from a proximal to a distal point, that is, the entire limb is first involved in the response and then gradually the more distal joints become, as it were, independent of the total movement.

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LE DÉVELOPPEMENT DU COMPORTMENT CHEZ LE CHAT FOETAL

(Résumé)

Le but de cette enquête a été la détermination de la nature précise qualitative du développement du comportement dans la vie du chat foetal avant la naissance, ou, au sens contraire, l'effort de remonter au commencement du comportement caractéristique du chaton nouveau-né avant sa naissance.

On a observé chaque portée de foetus pendant plusieurs heures dans des conditions approximativement normales. On a maintenu intacte la circulation ombilicale. Les observations ont été faites dans un bain de solution saline physiologique, la température étant maintenue à 37,5 C.±0,5 C. Pour rendre centaines des conditions si parfaites on a employé une technique spéciale d'opération et on a inventé un appareil de bain approprié. On a fourni aussi un appareil pour faire des photographies cinématographiques du comportement foetal.

On résume l'histoire des études du comportement foetal des mammifères.

On a commencé cette enquête par l'emploi d'animaux foetaux âgés de 20 jours (à partir du temps de la fertilisation) et on l'a continuée, à des intervalles d'un jour ou de deux jours, jusqu'aux chatons nouveau-nés âgés de 62 jours. Les chats foetaux âgés de 21 et de 22 jours ne possèdent pas la motilité. On a observé le comportement premièrement chez des foetus âgés de 23 jours. Comme la gestation a avancé, les réactions foetales sont devenues progressivement plus complexes. On a employé un total de 32 chattes enceintes.

On a employé divers stimuli pour faire naître les réactions foetals, et l'on a noté le comportement 'spontané'. L'expérimentateur a écrit les observations, et on a fait des photographies cinématographiques de chaque étape étudiée. Les données expérimentales, comprenant les notations de l'expérimentateur et ses analyses des photographies cinématographiques, sont brièvement présentées.

Sur la base des résultats de cette enquête on arrive aux conclusions suivantes:

1. Avant la naissance il y a un développement rapide, progressif et continu du comportement chez le foetus du chat.
2. Le développement du comportement progresse d'un état diffus, massif, variable, relativement non organisé, jusqu'à une condition dans laquelle beaucoup des réactions sont plus régulières en apparence, moins variables, mieux organisées et relativement individualisées.
3. Aux premières étapes du développement avant la naissance il paraît que le comportement progresse en suivant un cours céphalo-caudal.
4. Le développement de la sensitivité des zones réflexogènes subit un développement continu et de transition pendant quelque temps quand une stimulation assez vigoureuse de n'importe quel "lieu" du corps dans une grande aire fait naître des formes variables, diffuses, et non coordonnées du comportement, jusqu'à un temps postérieur quand un stimulus de lumière suffit, dans une aire beaucoup plus circonscrit, pour faire naître des formes précises, bien coordonnées, uniformes et moins variables, du comportement. La direction du développement est céphalo-caudale.
5. Les réactions "primitives" de respirer, de revenir à la posture ordinaire, de locomotion et de nourriture sont les produits d'un cours long et continûment progressif de developpement avant la naissance.

6. Le développement du comportement paraît premièrement dans la musculature grossière et plus tard dans la musculature fine.

7. Le comportement se développe dans chacun des membres d'un point proximal à un point distal; c'est-à-dire, le membre entier est premièrement engagé dans la réponse et puis peu à peu les articulations plus distales deviennent, pour ainsi dire, indépendantes du mouvement total.

CORONIOS

DIE ENTWICKLUNG DER TÄTIGKEIT BEIM KATZENFÖTUS

(Referat)

Die Absicht dieser Untersuchung war die Bestimmung der exakten qualitativen Natur der Entwicklung der Tätigkeit des Katzenfötus vor der Geburt, oder, umgekehrt, die Zurückführung der karakteristischen Tätigkeit des neugeborenen Kätzchens zu ihrem Anfang vor der Geburt.

Jeder Fötuswurf wurde mehrere Stunden lang unter verhältnismässig *normalen Umständen beobachtet. Der Nabelkreislauf [umbilical circulation]* wurde unversehrt erhalten. Die Beobachtungen wurden in einem Bade von physiologischer Salzlösung worin die Temperatur immer bei 37±.5° C. gehalten wurde, ausgeführt. Um solche optimalen Bedingen zu versichern wurde ein besonderes operatives Verfahren verwendet und ein geeigneter Badapparat erfunden. Es wurde auch ein Verfahren für die *Fabrizierung von Wechselbildern der fötalen Tätigkeit angeschaffen.*

Es wird die Geschichte der bisher ausgeführten Untersuchungen der fötalen Tätigkeit [fetal behavior] bei Säugetieren zusammengefasst.

Diese Untersuchung wurde angefangen an fötalen Tieren die 20 Tage (von der Zeit der Befruchtung aus gemessen) alt waren, und erstreckte sich, mit Abständen von 1 oder 2 Tagen, bis auf neugeborene Kätzchen 62 Tage alt (nach der Zeit der Befruchtung gemessen). Ein-und-zwanzig- und 22-Tage-alte Katzenfötuse bewegen sich nicht. Tätigkeit zeigte sich zuerst bei 23-Tage-alten Fötusen. Mit der Fortschreitung der Schwangerschaft wurden die fötalen Reaktionen progressiv komplizierter. Es wurden im Ganzen 32 trächtige Katzen für die Untersuchung verwendet.

Als Mittel zur Hervorrufung der fötalen Reaktionen wurden verschiedene Reize verwendet, und es wurde auch die "spontane" Tätigkeit notiert. Die Beobachtungen wurden von dem Versuchsleiter notiert und es wurden auch von jedem untersuchten Stadium der Entwicklung Wechselbilder gemacht. Es werden die experimentellen Befunde, einschliesslich der Protokolle des Versuchsleiters und der Analysen der Protokolle der Wechselbilder kurtz zusammengefasst.

Auf Basis der Resultate der gegenwärtigen Untersuchung zieht der Verfasser folgende Schlüsse:

1. Vor der Geburt findet eine rasche, progressiv und fortwährende Entwicklung der Tätigkeit des Katzenfötus statt.

2. Die Entwicklung der Tätigkeit schreitet von einem diffusen, massiven variablen relative ungeordneten Zustand zu einem Zustand fort, in dem viele der Reaktionen in ihrer Erscheinung regelmässiger, weniger variabel, besser organisiert, und relativ individualisiert sind.

3. In den relativ frühen Stadien der Entwicklung vor der Geburt scheint die Tätigkeit einen cephalokaudalen Lauf zu nehmen, d.h., in der Richtung von dem Kopf nach unten zu verlaufen.

4. Die Entwicklung der Empfindlichkeit der reflexogenen Körpergegende macht eine zusammenhängende und fortlaufende Entwicklung durch, von einer Zeit, während der eine etwas kräftige Reizung irgend eines "Körperfleckes" ["spot"] innerhalb eines grossen Körperteiles zur Hervorrufung variabler, diffuser, nicht-zusammenwirkender [uncoordinated] Tätigkeitsgestaltungen [behavior patterns] dient, bis zu einer später kommenden Zeit in der ein lichter Reiz, innerhalb eines viel beschränkteren Körperteiles nun zur Erzeugung genauer, gut zusammenhängender gleichmässiger und weniger variable Tätigkeitsgestaltungen genügt. Die Richtung der Entwicklung ist die vom Kopfe nach unten zu [cephalocaudal].

5. Die primitiven Reaktionen des Atmens, des sich Aufrichtens, des Gehens, und des sich Fütterns sind die Endresultate eines langen und beständig progressiven Entwicklungslaufes der vor-geburtlichen Entwicklung.

6. Die Entwicklung der Tätigkeiten erscheint zuerst in der groben und später in der feinen Muskulatur.

7. Die Entwicklung der Tätigkeit jedes Gliedes findet von dem Körperende auswärts [from a proximal to a distal point] statt, d.h., zuerst wird das ganze Glied durch die Reaktion in Anspruch genommen und dann werden die mehr entfernt liegenden [more distal] Gelenke sozusagen von der Gesemmtbewegung unabhängig.

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Child Behavior, Animal Behavior, and Comparative Psychology

A STUDY OF CERTAIN LANGUAGE DEVELOPMENTS OF CHILDREN IN GRADES FOUR TO TWELVE, INCLUSIVE*

From the Department of Educational Psychology of Northwestern University

By

LOU L. LABRANT

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I

THE NATURE OF THE PROBLEM

The intimate relation between language and the thought processes makes a study of language development important. Whether or not imageless thought can exist,[1] it is unquestioned that the large part of our thinking is in terms of language, implicit or explicit. Dewey (7, pp. 173-175) calls attention to four important functions which language performs: the classification, preservation, and application of individual meanings; and the organization of those meanings.

In general, two approaches are possible to an investigation of either collective or personal language development. We may, first, make a quantitative study, counting the number of different words used and the frequency of their appearance in the vocabulary. Usually such investigations have been related to the language development of children under six years. Comparable data for older individuals are usually secured by some sampling device. Even so small a vocabulary as that possessed by the preschool child offers difficulties, however. The same word or spoken symbol may serve several purposes. *Orange* is both a fruit and a color; one word to this child, two to that. *Good* has a certain meaning in *Be a good boy,* and a different one in *This apple is good.* Obviously, a word with advancement in the mastery of speech." She proposes length of sentence as a measure of the child's language development, but suggests this for preschool children only. Pal (25), studying one Bengalée child, reports the number of sentences and their length as used by a child of forty-one months. He notes the use of only one conjunction (ar=and). Guillaume (12, 13) finds the phrase appearing at eighteen months. He reports a detailed study of construction and flexions of word groups. Smith (31, p. 27), studying the chatter of 88 children from two to five years of age, concludes: "The most significant trend in the development of the sentence with increase of age was an increasing tendency toward the use of longer and more complete sentences. Other trends . . . were a decrease with age in the proportion of simple sentences to complex and compound sentences." Smith also classifies sentences functionally, using a technique similar to that of Boyd (3). The latter presents a most suggestive study of the language development of his child from the third to the eighth years, inclusive. Sentences (1250 recorded at each birthday from fourth to ninth) are classified as to their use (as statements, questions, commands, and exclamations), and the results compared with a similar analysis of conversation sentences taken from the works of eighteen novelists. Assuming that the latter samples represent adult conversation, he finds his child of eight using approximately the same proportion of the four types of sentences as do adults.

---

[1] For a brief summary of the various arguments in the language-thought controversy see Adams and Powers (1).

Boyd further classifies the sentences of his child according to their structure, finding a gradual increase in the proportion of dependent to independent clauses with increase in the child's age. He makes a like study of the complexity of adult conversation, again using as data the random samples of conversation taken from the writings of the eighteen novelists.

Kirkpatrick (16) early attempted an analysis of adult writing. He classified the words in samples of *Robinson Crusoe* according to parts of speech, and compared the relative proportion in each category with the proportion of such words in the dictionary. His technique is similar to that used by writers previously mentioned as studying the language of preschool children.

An interesting language study with emphasis on thought rather than on language *per se* has been developed by Piaget. His results are available in four volumes (26-29). Piaget offers a detailed analysis of the child's conversation in order to disclose the kind of thinking (social or egocentric) he does, and the degree to which his reasoning approaches that of the adult. The studies include reports of children from three to twelve years. In *Judgment and Reasoning in the Child,* Piaget makes extensive interpretations of the child's use of certain conjunctions, and distinguishes between the functions of certain types of clauses in child and adult language. Piaget's assumption is that language is in general an index of thought, but he compares objective experiments with verbal ones.

The present study proposes to investigate the language development of children from Grades 4 to 9, inclusive, using the clause as the unit of comparison.

Smith (31, p. 68), McCarthy (19, pp. 93-110), and Nice (24) suggest length and complexity of sentence as significant measures with preschool children; but the identification of the sentence becomes a matter of individual interpretation in the compositions of older individuals. The child says: *"I bought a ball. Jane bought a doll."* We have two sentences, or one, our result depending upon punctuation. The introduction of *and* gives one long compound sentence instead of two short simple ones, although the most important facts of expression remain the same. That is, the child, whether he uses two simple sentences or one compound one, is stating definitely two judgments of equal merit, and expressing them in parallel forms. Length of clause, therefore, and type of clause appear the more significant measures. Since every finite predicate indicates the existence of a clause, approach to the investigation is made through the tabulation of predicates.

The significance of the predicate in verbal expression has long been recognized and has in consequence been a popular topic in logic. James Mill calls attention to the rôle of predication. He says (20, pp. 161-162):

> "By a few simple examples, the reader may render familiar the use of predication, as the grand expedient, by which language is enabled to mark not only sensations and ideas, but also the order of them."
>
> "And it [predication] is the grand contrivance by which the marks of sensations and ideas are so ordered in discourse, as to mark the order of the trains, which it is our purpose to communicate, or to record."

John Stuart Mill adds in comment (21, p. 164, footnote):

> "Predication may thus be defined, a form of speech which expresses a belief that a certain co-existence or sequence of sensations or ideas, did, does, or under certain conditions, would take place; and the reverse of this when the predication is negative."

Hobbes called attention to the importance of the predicate as compared to other elements in the sentence. His theory (see 21, p. 163, footnote), denominated by Leibnitz the *"plus quam nominalis"* theory, is of interest here as suggesting the inadequacy of a mere catalog of words of vocabulary in a study of language development.

The finite predicate, or the clause which it dominates, is therefore proposed as the unit of measurement because every such predicate posits a judgment.[3] The complete predicate rather than individual verb-words is used, because functionally two verb-words may be of no more importance than one. For example, *I have seen him* is certainly not twice as significant as *I saw him*. This distinction is suggested here because many studies of language have discussed the proportion of verbs to the total number of words used, but have counted verb-words instead of complete verb units.

Predicates are not necessarily of equal significance or importance in a given sentence. Relations between predicates signify relations between judgments. A gain in thought expression is made when the child passes from *Doll, pretty* to *My doll is pretty.* Relation between *doll* and *pretty-ness* is clearly stated. Just so, there is a further gain in expression of relation when *We were in town and I bought a hat* becomes *I bought a hat when we were in town.* Two judgments have been seen in their relation to each other. Jesperson's conclusions concerning sex differences may be questioned in the following quotation, but his interpretation of the rôle of subordination of clauses is based on his thorough knowledge of language structure. He says (15, p. 251):

---

[3] *Judgment* is here used in a popular rather than in the logician's sense. Creighton says: "The logical proposition, as the expression of an act or thought, corresponds to the grammatical sentence. Not every sentence, however, is a logical proposition" (5, pp. 84-85).

> "If we compare long periods as constructed by men and women, we shall in the former find many more instances of intricate or involute structures with clause within clause, a relative clause in the middle of a conditional clause or vice versa, with subordination and subsubordination, while the typical form of long feminine periods is that of co-ordination, one sentence or clause being added to another on the same plane and the gradation between the respective ideas being marked not grammatically, but emotionally, by stress and intonation, and in writing by underlining. In learned terminology we may say that men are fond of hypotaxis and women of parataxis."

As was suggested previously in this chapter, it is difficult to study language development in any but purely quantitative aspects without at the same time considering the thought processes involved. Piaget calls attention to this intimate relation, and to the types of thought changes suggested by changing clausal relations, in the following quotations:

> "To reason logically is so to link one's propositions that each should contain the reason for the one succeeding it, and should itself be demonstrated by the one preceding it. Or at any rate, whatever the order adopted in the construction of one's own exposition, it is to demonstrate judgments by each other. * * * If, therefore, the child remains for a long time ignorant of the need for demonstration, this is bound to have an effect upon his manner of reasoning. As we have already pointed out, the child is not really aware of the necessity of arranging his sentences in logical order" (27, p. 1).
>
> "The phenomenon of juxtaposition is very frequent in child thought. A well-known and particularly striking example has been signalled in the case of children's drawings and has been referred to as 'synthetic incapacity'. * * * This synthetic incapacity covers more ground than one would think, for it is really the mark of the whole of childish thought up to a certain age. We have already observed it in connexion with understanding between children. We have tried to show that occasions abound when, instead of expressing the relation between two propositions by the word 'because' (as had been done in the corresponding adult communication) or in any other way, the child was content to juxtapose these propositions without any further ado, whether or no he had been conscious of any causal connexion between them. Now, in three quarters of such cases, the child who was spoken to did not realize that such a connexion was in question, and could therefore see nothing more than two statements which were independent of each other" (27, p. 3).

In the present study the writer proposed to discover only *how* the growing child expresses himself in regard to his use of independent and dependent clauses, and to leave the question of *why* he so expresses himself. The procedure is as follows.

The written composition of 1007 persons, ranging in mental age from 101 months to superior adult level, is examined, and the total number of clauses used by each individual classified. Clauses (or predicates) are divided first into two main groups, independent and dependent. Dependent clauses, as will be explained in detail in Chapter II, are further classified as to general use (as adjective, adverb, or noun elements), and adverbial clauses subdivided according to their specific functions in expressing time, place, purpose, and so forth.

No absolute standards of clause relation are, of course, conceivable. *I played with fire and I was burned* may be the correct statement of two events of equal importance from the standpoint of the individual speaking. What constitutes an idea of independent or major importance is a matter of judgment. Consequently, this study offers merely a statement of the proportions of dependent clauses found at the various mental and chronological ages of the individuals whose language is studied.

II

SOURCE AND NATURE OF DATA; TECHNIQUE OF ANALYSIS

A. GROUPS STUDIED

Data for the study were obtained by analyzing the written composition of three groups of individuals, designated as Groups A, B, and C. The writing of Group A was analyzed as to both structural and functional nature of the clauses used (Chapters III and IV); while the clauses used by Groups B and C were analyzed as to structure only (Chapter V).

Group A consists of 482 children enrolled in Grades 4 to 9, inclusive, in the Baldwin, Holton, and Lawrence (Oread Training) schools in Kansas; Group B, of 504 pupils enrolled in Grades 9 to 12, inclusive, in Leavenworth and Lawrence (Oread Training), Kansas, high schools; Group C, of 21 psychologists, contributors to *The Psychologies of 1930* (22). In all, 1007 cases are used. There are 14 duplicates, individuals included in both Groups A and B.

Two types of data were secured for each of the first two groups (A and B): *Type 1,* mental-test scores, chronological ages, and resulting intelligence quotients; and *Type 2,* written compositions. Both types of data for each group were secured on the same or successive days. Mental tests were given all of the 986 cases: for Grades 4 to 6, inclusive, the *Haggerty Intelligence Examination, Delta 2* (14); for Grades 7 to 12, inclusive, *The Terman Group Test of Mental*

Ability, Form A (33). Tests were administered by the writer and two assistants, high-school instructors experienced in the administration of tests. All tests were carefully scored under the supervision of the writer, who rechecked a random sampling to determine the accuracy of scoring. All computations of chronological age and intelligence quotient were checked twice.

Nature of Group A. Both Holton and Baldwin are small Kansas towns, with populations drawn largely from rural communities. Oread Training high school is a tuition-free high school maintained at the University of Kansas for experimental and teacher-training purposes.

Table 1 shows the distribution of mental and of chronological ages for Group A; Table 2, a distribu-

TABLE 1

DISTRIBUTION OF CHRONOLOGICAL AND MENTAL AGES FOR GROUP A, 482 KANSAS PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM HOLTON, BALDWIN, AND LAWRENCE (OREAD TRAINING) SCHOOLS

	Frequencies	
Months	CA	MA
101-110	7	16
111-120	40	21
121-130	46	37
131-140	44	42
141-150	61	45
151-160	67	80
161-170	71	72
171-180	76	64
181-190	47	49
191-200	Over 191* 23	33
201-210		14
211-220		6
221-230		3

*Not computed over 16 years.

TABLE 2

DISTRIBUTION OF INTELLIGENCE QUOTIENTS, GROUP A, 482 KANSAS PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM HOLTON, BALDWIN, AND LAWRENCE (OREAD TRAINING) SCHOOLS

IQ	Frequency			
	Holton	Baldwin	Oread Tr.	Total
60- 64.9	1			1
65- 69.9	1	3		4
70- 74.9	3	1		4
75- 79.9	3	9		12
80- 84.9	23	6	1	30
85- 89.9	24	20	1	45
90- 94.9	21	22	1	44
95- 99.9	31	21	4	56
100-104.9	32	20	6	58
105-109.9	38	27	3	68
110-114.9	28	15	2	45
115-119.9	18	19	4	41
120-124.9	12	10	1	23
125-129.9	5	6	3	14
130-134.9	6	3	1	10
135-139.9	6	3		9
140-144.9	9	3		12
145-149.9	2	1		3
150-154.9	1	2		3
Totals	264	191	27	482

Mean IQ, 104.55
Sigma, ±16.4

tion of intelligence quotients. Chronological ages range from 101 to 192 months (not computed above 16 years); mental ages from 101 to 230 months. The range of intelligence quotients is from 60 to 154. There is a slightly larger percentage of cases in the upper levels than normally is found. A mean intelligence quotient of 104.55 and sigma value of 16.4 indicate an approximately normal group, however, according to Terman's (32, pp. 78-79) norms. Approximately 68 per cent of the cases in the present study fall between 88 and 121; or, stated conversely, 16 per cent fall below 88, and 16 per cent above 121. Terman finds 15 per cent of unselected school children falling below 88, and 15 per cent above 113. Cases in the present study, therefore, depart from Terman's standards by a slight superiority only.

Since Group A was to form the basis for the detailed analytical study, the writer chose to select it from communities in which there was little likelihood of finding pupils with language handicaps. So far as he was able to determine, no child included in the 482 is from a home where English is not spoken.

Nature of Group B. The second group (B) consists of 504 pupils, Grades 9 to 12, inclusive; 414 from the Leavenworth (Kansas) and 90 from Oread Training (Lawrence, Kansas) high schools. The Leavenworth pupils number all who were available during the unassigned teaching hours of Miss Bertha Roberts, instructor, who administered the tests and secured the written work; and Oread pupils, all of those present in the forenoon on days when data were secured.

Leavenworth is a town with varied population, the location of an officers' training fort, a Federal penitentiary, and a soldiers' home. In addition to the above institutions, Leavenworth supports several manufacturing industries.

The composition of the Oread high school has been presented previously.

Table 3 presents the distribution of chronological and mental ages for Group B. Range in mental age is from 121 to 240 months. The lowest chronological age is 151 months (12 years, 7 months). Table 4 shows

TABLE 3

DISTRIBUTION OF CHRONOLOGICAL AND MENTAL AGES FOR GROUP B, 504 KANSAS PUPILS, GRADES 9 TO 12, INCLUSIVE, FROM LEAVENWORTH AND LAWRENCE (OREAD TRAINING) HIGH SCHOOLS

Months	Frequencies CA	Frequencies MA
121-130		1
131-140		2
141-150		10
151-160	7	17
161-170	28	58
171-180	104	80
181-190	124	99
191-200	Over 191* 241	106
201-210		68
211-220		39
221-230		16
231-240		8

*Not computed over 16 years.

TABLE 4

DISTRIBUTION OF INTELLIGENCE QUOTIENTS, GROUP B, 504 KANSAS PUPILS, GRADES 9 TO 12, INCLUSIVE, FROM LEAVENWORTH AND LAWRENCE (OREAD TRAINING) HIGH SCHOOLS

IQ	Frequencies
65- 69.9	1
70- 74.9	1
75- 79.9	8
80- 84.9	13
85- 89.9	37
90- 94.9	64
95- 99.9	84
100-104.9	99
105-109.9	81
110-114.9	55
115-119.9	30
120-124.9	19
125-129.9	7
130-134.9	4
135-139.9	1

Mean IQ, 102.55
Sigma, ±10.82

the distribution of intelligence quotients. Intelligence quotients range from 65 to 140. Mean quotient is 102.55, with a standard deviation of 10.82. Group B approximates Terman's norms (see previous discussion for Group A) more closely than does Group A. Since 68 per cent of the cases have intelligence quotients falling between 91 and 114, the group forms a most satisfactory unit for determining the language tendencies of average individuals.

Nature of Group C. Twenty-one eminent psychologists, contributors to *The Psychologies of 1930* (22), constitute Group C. The volume contains 25 articles. Spearman has two contributions, however, and three other discussions (those by Adler, Janet, and Pavlov) are translations. The volume therefore contains the writing in original English of but 21 different individuals. These persons were chosen because they were as a group distinctly successful, and, by implication, mentally superior; because they were here writing on an abstract subject which should involve relationships between judgments in a high degree; and because, their subjects being similar in purpose, their writing should be comparable. Moreover, since the papers were prepared in order to present certain positions clearly and as briefly as possible, they should be less marked by artificial structure used for the sake of style than many collections of adult writing would be.

B. Composition Data

Compositions for Group A. Since the purpose of the study is to determine the tendency of the child to express relations, it appeared desirable to secure written matter approaching as nearly as possible natural expression. The writer acknowledges that it is impossible to accomplish this result perfectly. Pupils in Group A were given the following explanation and request by a visitor. The wording and tone of the speaker were modified slightly to adapt the request to the various grade levels.

> "I have come here from the University of Kansas, where there are a good many people studying about how schools ought to be run. They have just been very much interested by some persons who think that we waste much time because we school folk go off on vacations all summer long. They say that business men and farmers work all the year, and that it is foolish for teachers and pupils to rest all summer. Now, many of the people at the University think it might be a good idea to try longer terms, but they say that the school children probably know more about whether vacations are a waste than do any other people. Won't you please take these sheets of paper, and write as rapidly as you can what you think about it? We have only twenty minutes; so perhaps you will have to hurry."

The foregoing directions were given in an attempt to secure (*a*) papers written so rapidly that attention to punctuation, spelling, and form would not modify the expression; (*b*) written work colored as little as possible by the schoolroom attitude and adult quotations; and (*c*) material concerned with the vital interests and experiences of the children. That the results are at least in part satisfactory is evidenced by the content. The average length of the compositions is approximately 130 words. Considerable disrespect for school limitations and products is expressed freely. The sincerity and consequent absorption of the writers in the content are indicated by threats to quit school, to join the navy, to show in various ways marked defiance to any move to lengthen the school year. In only one case does the pupil generalize throughout the paper. In the other 481 papers the pupils enumerate their own experiences as evidence. The assigned subject gives opportunity for argument, exposition, description, and narration; but narration of summer experiences predominates. The compositions were secured within two days of the time when the intelligence tests were given.

Compositions from Group B. Because they were too mature to be impressed by the directions given the younger children, pupils in Group B were asked to write about the best vacations they had had, or to discuss the merits of a three-months vacation. Oread pupils were given the option of writing about a favorite book. Pupils in this school are unusually proud of their reading accomplishments, and consequently many chose the second theme. Tests were given and the writing secured from Leavenworth pupils during the first weeks of May, when vacation was a fascinating topic.

Material from Group C. For the purpose of the present analysis, two samples were taken from the discussion of each psychologist in Group C. Approximately the first 20 lines of each article in *The Psychologies of 1930* and the first 20 lines of the tenth page of each article gave 40 lines from each writer. The sample was taken to the first period following the 20-line limit. In articles having fewer than ten pages, the first 20 lines on the last page were used instead of lines on the tenth page.

C. TECHNIQUE OF ANALYSIS

Analysis of Compositions by Group A. The papers from 482 pupils in Group A were read carefully, and each finite predicate expressed was tabulated according to its use in the sentence.

Implied predicates were not included, no matter how clear the implication, except where the omitted verb was an auxiliary whose complementary verb was expressed. This plan was arbitrary, but was adopted because of the impossibility of deciding where implications were clear in the mind of the writer and where they were felt by the reader only. *I work harder than you,* requires the conclusion, *work;* but the child probably does not think *work.* The frequency with which children use a progressive or an emphatic form made important the decision concerning such expressions as *I am studying books and working hard.* As was indicated above, predicates containing two or more participles or complementary infinitives after a single auxiliary were counted as two or more predicates. This plan was followed because apparently the younger children often lose recognition of the introductory auxiliary and use the verb complement as a complete predicate. The following sentence illustrates: *In summer we are going to Texas, and going to see our relatives, and driving in a car and have a good time.*

The full classification in this study appears in Table 5, and follows closely the classification given by Smart (30, pp. 115-116).

TABLE 5

CLASSIFICATION OF FINITE VERBS, USED IN ANALYSIS OF COMPOSITIONS WRITTEN BY GROUP A

I. Complete predicates in independent clauses
II. Complete predicates in dependent clauses, used as
    A. Adverbs, to express
        1. Time
        2. Cause
        3. Condition
        4. Concession
        5. Place
        6. Purpose or result
        7. Comparison
    B. Nouns
    C. Adjectives

Inaccuracies in child writing furnished further difficulties in classification. The use of *go* and *go and* appears in a variety of expressions where *go* is apparently misused as an auxiliary. *I often go play ball, We often go and play, We will go visit, We will go and visit* may be interpreted as having either one or two predicates to each sentence. It is doubtful whether there is any difference in the child's mind between *go play, go and play,* or simply *play.* Quite possibly *go* is merely used as an auxiliary, later to be dropped as the *Let's play like* (often shortened to *Let's p'like*) later becomes merely *Let's play.* In this study these particular uses of *go* are considered auxiliary only, and one predicate is recorded for both *go and play* and *go play.*

Difficulties were also found in classification of certain adverbial predicates. Such a clause as *When I am good* in the sentence, *Mother pays me when I am* *good,* would seem to an adult to express condition rather than time. It is here classed in the time category, however, because the actual statement expresses time, and because it is impossible to know whether the writer may not have been as much concerned with the time as with the condition. The problem illustrates the complications found in attempting any objective study of language.

Purpose and result categories are combined because of the difficulty in distinguishing purpose and result in the writing of the younger children. In cases where no definition seems applicable, the writer has classed the predicate according to the simplest interpretation of meaning.

As a further study of verb units, occurrence of infinitives was recorded. The infinitive is here used in a limited sense rather than as including all verb forms which are not finite. Smart's (30, p. 78) definition is accepted: "An infinitive is a form of a verb introduced normally by the sign *to,* and used as a noun, an adjective, or an adverb." Two general categories were used: (1) the infinitive combined with a finite form of *be* or *be going* to indicate future time; and (2) all other infinitives.

Analysis of Writing of Groups B and C. Predicates used by Groups B and C were classified under two headings only: (1) predicates in independent clauses; and (2) predicates in dependent clauses.

Summary

Individuals whose language is here studied are 986 public-school pupils in Grades 4 to 12, inclusive, and 21 eminent psychologists. In all, 1007 cases are included. They range in mental age from 101 months to superior adult; in intelligence quotient from 65 to above 150; and in chronological age from 101 months to above 70 years.

The written composition analyzed totals 161,518 words, including 20,320 predicates or clauses, 6,596 of which are dependent, and 13,724, independent. Table 6 presents these facts.

TABLE 6

Summary of Extent of Data Presented in This Study

	Number of cases	Number of words	Number of predicates Independent	Number of predicates Dependent	Total
Group A	482	66,256	6,649	2,507	9,156
Group B	504	82,662	6,627	3,708	10,335
Group C	21	12,600	448	381	829
Totals	1,007	161,518	13,724	6,596	20,320

III

THE WRITING OF GROUP A ANALYZED AS TO TENDENCY TO USE DEPENDENT PREDICATES

This chapter presents a study of the writing of Group A, 482 pupils in Grades 4 to 9, inclusive, to discover whether an increasing tendency to use subordinate clauses accompanies maturation, and, if so, to what degree it is a correlate of mental age as measured by the tests used, and to what degree a correlate of chronological age. Use of dependent clauses is expressed by the *subordination index.* This index, as defined in the present study, is the ratio of the number of dependent predicates used by each individual or group to the total number of predicates used by that individual or group, the ratio being expressed in percentage. If the child uses 10 predicates, 4 of which are dependent, his subordination index is therefore 0.4 or 40 per cent.

The writing of the 482 pupils contains 66,256 words and 9,156 predicates. Table 7 presents the total number of words, and of predicates, and the occurrence of predicates in main and dependent clauses.

TABLE 7

FREQUENCY OF MAIN AND SUBORDINATE PREDICATES IN THE WRITING OF GROUP A, 482 CHILDREN, GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

Total number of words written	66,256
Average length of themes (words)	137.4
Total number of predicates	
In independent clauses	6,649
In dependent clauses	2,507
In all clauses	9,156

Papers for the 482 pupils in Group A were arranged according to the mental ages of the writers and divided for purposes of comparison into units of ten mental-age months each (lowest group, 101-110 months; highest group, 231-240 months). The compositions were analyzed carefully and predicates tabulated according to the outline given in Chapter II (see Table 5). Subordination index for each child, and mean and median indexes for each mental-age unit, were computed. To insure correctness in the predicate analysis, one-fourth of the papers were analyzed a second time. Only 26 changes in classification were made on this recheck. Clauses from all of the rechecked papers and their classification are presented in Chapter IV. Table 8 summarizes the data from the papers written by Group A.

TABLE 8

MEAN AND MEDIAN SUBORDINATION INDEXES FOR MENTAL-AGE UNITS OF TEN MONTHS FOR GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS

MA (months)	Median index	Mean index	Frequencies
101-110	13.7	17.8	16
111-120	9.5	13.2	21
121-130	17.5	21.2	37
131-140	18.0	19.9	42
141-150	23.6	27.6	45
151-160	28.7	28.8	80
161-170	33.2	33.5	72
171-180	30.0	31.4	64
181-190	31.4	32.5	49
191-200	30.5	30.2	33
201-210	30.0	34.2	14
211-220	27.5	30.0	6
221-230	22.5	25.8	3
		Total	482

Table 8 shows a tendency toward increase in proportion of dependent verbs with increase in mental age. Both mean and median measures show approximately twice as many subordinate clauses used at the upper levels as at the lower. The median index for the lowest group, mental age 101-110 months, is 13.7; while the index for the 201-210 group is 30.0. (Cases in groups higher than this latter one are too few for comparison.) Similarly, the mean for the lowest group is 17.8; and for the 201-210 group, 34.2.

Attention is directed here to the brevity of the samples (average per pupil, 137.4 words), and to the consequent probability that they should not be considered adequate measures of *individual* language development. Nevertheless, correlation of subordination indexes with mental-age ratings [Pearson product-moment formula; see Garrett (11, pp. 163 ff.)] gives a coefficient of 0.29±.03.

Further analysis of Table 8 reveals that both mean and median indexes for mental-age group 111-120 months are lower than corresponding ones for the preceding group, mental age 101-110. Similar irregularities appear at the upper levels. Study of these extreme units suggests that the irregular increase in the index may be due to the selective character of the mental-age units concerned. Writing samples were obtained from all pupils in Grades 4 to 9, inclusive. Holton pupils wrote in February and Baldwin pupils in March. (Data for Oread pupils were gathered in October, but do not affect these lower levels.) The average age in May of pupils in the fourth grade is given by McCall (18, p. 34) as 128 months. Consequently, those children with mental age 101-120 months may be expected to have low intelligence quotients and relatively high chronological ages. Examination of the data shows that this supposition is correct. The median intelligence quotient for the first unit (mental age 101-110 months) is 83.5; the median chronological age, 131.6 months. For the next higher unit (111-120 months) the median intelligence quotient is 90; the median chronological age, 127.5 months.

TABLE 9

MEDIAN INTELLIGENCE QUOTIENT, CHRONOLOGICAL AGE, AND SUBORDINATION INDEX FOR EACH MENTAL-AGE UNIT, GROUP A, 482 PUPILS IN GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

(*a*) MA (months)	(*b*) Median IQ	(*c*) Median CA	(*d*) Median subordination index	(*e*) Number of cases
101-110	83.5	131.6	13.7	16
111-120	90.0	127.5	9.5	21
121-130	98.5	128.7	17.5	37
131-140	104.16	128.8	18.0	42
141-150	97.5	152.0	23.6	45
151-160	99.7	159.6	28.7	80
161-170	100.9	165.7	33.2	72
171-180	108.25	164.3	30.0	64
181-190	108.5	173.4	31.4	49
191-200	117.8	170.9	30.5	33
201-210	118.3	167.0	30.0	14
211-220	125.0	173.7	27.5	6
221-230	136.0	159.0	22.5	3

Table 9 gives median chronological age, intelligence quotient, and subordination index for each mental-age unit. Comparison of columns *c* and *d* discloses a tendency for rise in chronological age to be associated with an increment in the subordination index. This finding

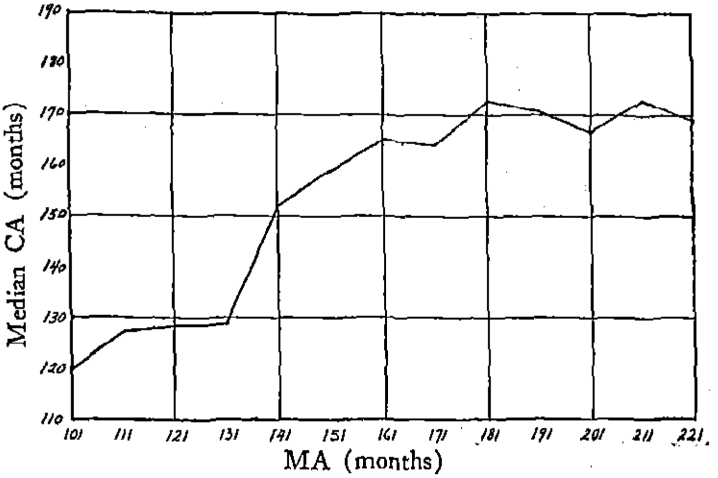

FIGURE 1
CURVE OF MEDIAN CHRONOLOGICAL AGES FOR SUCCESSIVE MENTAL-AGE UNITS, GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS (FROM TABLE 9)

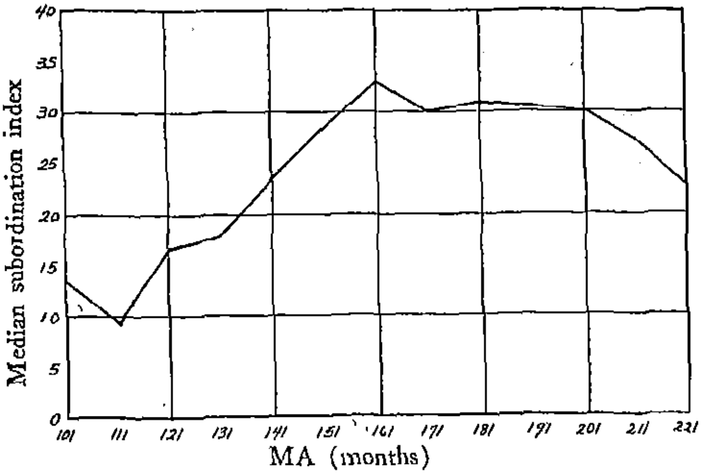

FIGURE 2
CURVE OF MEDIAN SUBORDINATION INDEXES FOR SUCCESSIVE MENTAL-AGE UNITS, GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS (FROM TABLE 9)

is in harmony with the inferences from Table 8 and may explain the apparent contradiction of the first two units therein. The opposite relation appears at the upper levels, where high mental age is combined with low (comparatively) chronological age, and index is also lowered. Figures 1 and 2, presenting graphically both median subordination index and chronological age at each mental-age level (data from columns *c* and *d*, Table 9), show a marked tendency for index variations to parallel those of life age, when mental age is constant.

TABLE 10

MEAN AND MEDIAN SUBORDINATION INDEXES FOR CHRONOLOGICAL-AGE UNITS OF TEN MONTHS FOR GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS

CA (months)	Median index	Mean index	Frequencies
101-110	11.25	10.0	7
111-120	17.5	19.0	40
121-130	17.8	18.8	46
131-140	22.0	21.25	44
141-150	28.4	27.9	61
151-160	29.4	32.3	67
161-170	30.7	31.1	71
171-180	30.0	30.6	76
181-190	33.6	34.4	47
191 and over	36.25	36.6	23
		Total	482

Table 10 presents the data just discussed by chronological rather than mental age. Correlation of the subordination index with chronological age (Pearson product-moment formula) gives a coefficient of 0.41 ± .03, slightly higher than that with mental age.

From the preceding it is apparent that there is a positive relation between the increasing tendency to subordinate verbs and growth in both mental and chronological age, although, as previously stated, samples here included are probably not sufficient to measure individuals. Use of partial correlation to determine the rôle of either mental or chronological age is not justified since in the light of the above coefficients the subordination index appears to be a correlative both of chronological and of mental age. Burks discusses this point (4, pp. 12-13):

> "In any study of causation we are partialling out too much when we render constant factors which may in part or in whole be caused by either of the two factors whose true relationship is to be measured, or by still other unmeasured remote causes which also affect either of the two isolated factors."

In order, therefore, to distinguish the relations of the subordination index to mental and to chronological age, and to consider group tendencies rather than individual scores, the cases within each mental-age group were further divided. Two subdivisions were made: (A) those whose chronological age is lower than the lowest mental age within the unit; and (B) those with chronological age equal to or above the lowest mental age of the unit. For example, in the mental-age unit 121-130 months, Division A contains all those cases with chronological age up to and including 120 months; Division B, those with chronological age 121 months or above. Division A is therefore a superior, and Division B, an inferior, group as measured by intelligence quotient. Table 11 shows the results of this

TABLE 11

COMPARISON OF MEDIAN INDEXES FOR LOW AND HIGH CHRONOLOGICAL DIVISIONS WITHIN EACH OF ELEVEN MENTAL-AGE UNITS FOR GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

	CA (months)		Number of cases			Median Index		
MA (months)	Div. A (High IQ)	Div. B (Low IQ)	Div. A	Div. B	Total	Div. A	Div. B	Total
101-110		111-178	0	16	16		13.7	13.7
111-120	108-109	111-179	2	19	21		10.25	9.5
121-130	110-120	121-192	12	25	37	17.5	17.5	17.5
131-140	110-130	131-169	23	19	42	17.9	19.75	18.0
141-150	110-140	141-190	15	30	45	20.5	26.7	23.6
151-160	112-150	151-192	30	50	80	25.8	30.6	28.7
161-170	112-160	161-192	29	43	72	29.2	38.5	33.2
171-180	113-170	171-192	41	23	64	29.6	30.5	30.0
181-190	127-180	181-192	36	13	49	31.0	34.1	31.4
191-200	142-188		33		33	30.5		30.5
201-230	151-181		23		23	29.5		29.5
	Totals		244	238	482			

Division A: Cases whose chronological age is less than lower limits of mental-age unit.

Division B: Cases whose chronological age is above lower limit of mental-age unit.

division. Median rather than mean scores are given because of the small number of cases in the divisions.

It may be seen from Table 11 that median indexes of subordination are consistently larger for the low-intelligence-quotient group than for the higher at each mental-age level save one (121-130), where the indexes are identical. Reference to column 2 shows that at this level the 12 cases in the high-intelligence-quotient division (A) are but slightly superior, the chronological ages (110-120) approaching closely to mental age (121-130). If subordination is a correlative of chronological-age development, this index should approach —as it does—that of the low-intelligence-quotient (high-chronological-age) division. Conversely, at the last interval, where chronological age is actually lower (see column 2) than at the previous level, the index again drops slightly. Figure 3 presents graphically the data from the seventh and eighth columns of Table 11, just discussed.

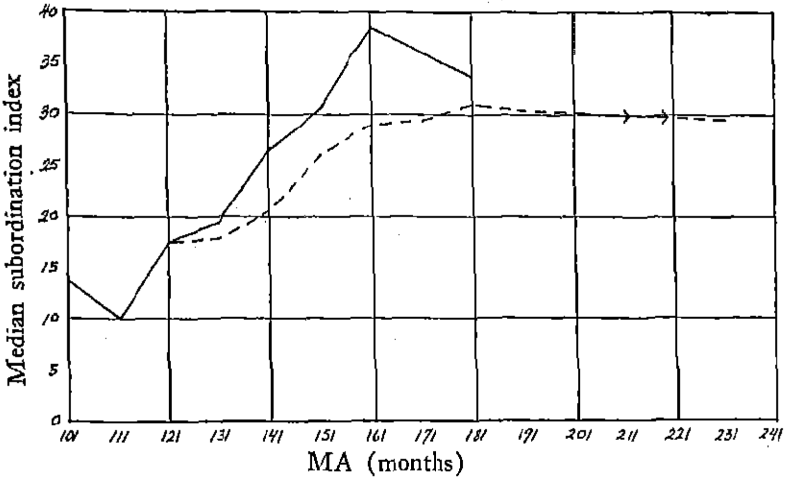

FIGURE 3
CURVES SHOWING RELATIVE INCREASE IN SUBORDINATION INDEX FOR HIGH- AND LOW-IQ GROUPS, GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS
---- high IQ group (Division A, Table 11)
—— low IQ group (Division B, Table 11)

Figures 4 and 5 are growth curves showing the relation of the index of subordination to mental and to chronological age. Although individual indexes derived from the brief samples written by the 482 children do not give a high correlation with either mental or chronological age, the curves here presented suggest that there is a relation between maturation and the development of complex language structure.

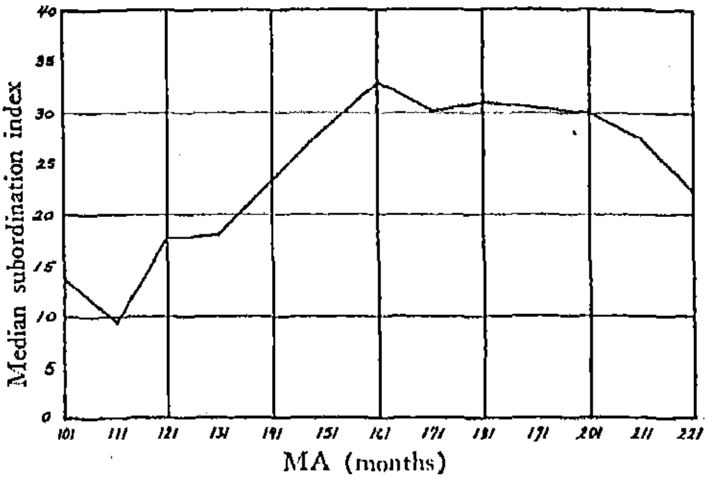

FIGURE 4
CURVE OF MEDIAN SUBORDINATION INDEXES AT INCREASING MENTAL-AGE LEVELS, GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS (FROM TABLE 8)

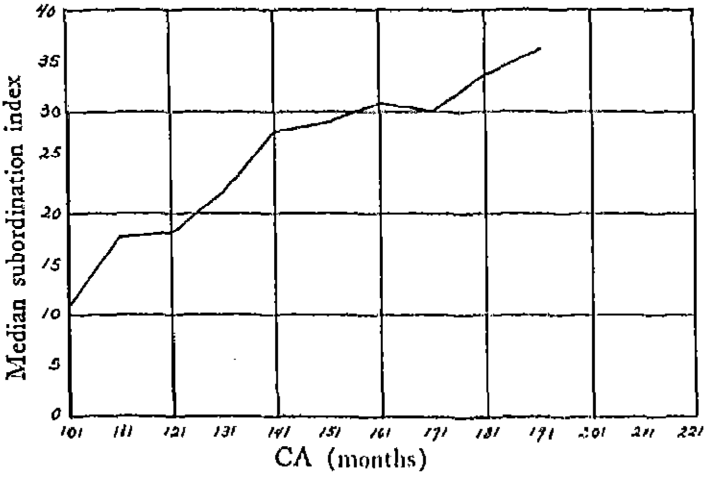

FIGURE 5
CURVE OF MEDIAN SUBORDINATION INDEXES AT INCREASING CHRONOLOGICAL-AGE LEVELS, GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS (FROM TABLE 10)

SUMMARY

Language development, as an accompaniment of mental- and chronological-age growth, is marked by an increase in the percentage of subordinate predicates to total predicates used, if we may judge from the rapidly written composition of children in Grades 4 to 9, inclusive.

The subordination index is a function of both mental and chronological age, but is markedly influenced by chronological age when mental age is constant.

The foregoing statements suggest the following questions:

1. Does the fact that the subordination index agrees more closely with chronological than with mental age indicate that mental tests used in the present study fail to sample all mental abilities? Or, in other words, that a sense of relation as indicated by use of dependent clauses is not measured by the mental tests used? (The statement is frequently made that group intelligence tests are too highly influenced by language skill. The results here presented would indicate that, if this is so, the kind of language skill demanded for responses is not that represented by the subordination index here discussed, since this index is markedly influenced by chronological age *within mental-age limits.*)
2. Does the influence of chronological age on the subordination index indicate that experience (environment) is a considerable factor in modifying language skill?
3. Does the influence of chronological age on the subordination index indicate that language development is dependent upon maturing structure?

IV

THE WRITING OF GROUP A ANALYZED AS TO THE FREQUENCY AND CONTENT OF THE VARIOUS KINDS OF DEPENDENT CLAUSES

A. FREQUENCY OF VARIOUS TYPES OF DEPENDENT CLAUSES

As was stated in Chapter II, the subordinate predicates used by Group A were classified as to the functions of the clauses in which they occurred. The three main divisions—noun, adjective, and adverb clauses—were first made. Adverb clauses were further subdivided according to Smart's (30, pp. 115-118) classification into clauses of time, place, cause, purpose and result, condition, and concession. Two additional classifications of adverb clauses given by Smart, clauses of manner and those used to modify adjectives, were not found useful. No child used a clause of manner; and only two, clauses modifying adjectives. One of the latter clauses had as its meaning result and was so classified; the other, meaning time, was placed in that category.

Table 12 presents a distribution of the various types of subordinate clauses as they appear at the several mental-age levels, and Table 13 gives the same data in percentages, but with mental-age groups of 20 instead of 10 months each. Frequencies for the three upper levels are so few as to make the figures for these units of little significance.

TABLE 12

RELATIVE FREQUENCIES OF VARIOUS USES OF 2,507 SUBORDINATE PREDICATES, FOUND IN THE WRITING OF GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS

MA	Number of papers	Number of subordinate predicates									
		Adverbial							Noun	Adjective	Total
		Time	Cause	Condition	Concession	Place	Purpose, result	Comparison			
101-110	16	14	6	2			2	3	9	4	40
111-120	21	16	10	2		1	5		10	10	54
121-130	37	77	20	6	1	3	7	1	38	28	181
131-140	42	50	24	10		11	1	5	55	35	191
141-150	45	56	24	14	1	6	8	7	56	37	209
151-160	80	106	53	33	1	5	10	5	102	78	393
161-170	72	119	65	39	2		11	13	92	97	438
171-180	64	78	42	47	2	4	19	8	88	91	379
181-190	49	62	43	12	1	2	7	9	59	67	262
191-200	33	51	18	26	2	3	2	6	60	45	213
201-210	14	20	9	10	1	8	4	1	17	24	94
211-220	6	5	3	1					9	13	31
221-230	3	6	4			2			3	7	22
Totals	482	660	321	202	11	45	76	58	598	536	2507
Percentages		26.30	12.80	8.05	0.40	1.80	3.03	2.30	23.80	21.40	99.88

TABLE 13

PERCENTAGES OF THE VARIOUS USES OF 2,506 SUBORDINATE PREDICATES FOUND IN THE WRITING OF GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS

		Number of subordinate predicates (percentage)									
		Adverbial							Noun	Adjective	Total
MA	Number of papers	Time	Cause	Condition	Concession	Place	Purpose, result	Comparison			
101-120	37	31.9	17.0	4.2	0.0	1.1	7.4	3.2	20.2	15.0	100.0
121-140	79	34.1	11.8	4.3	0.3	3.0	2.1	1.6	25.0	16.9	99.1
141-160	125	26.9	12.8	7.8	0.3	1.8	3.0	2.0	26.2	19.0	99.8
161-180	136	24.1	13.1	10.5	0.5	0.5	3.6	2.6	22.0	23.0	99.9
181-200	82	23.8	12.8	8.0	0.6	1.1	2.0	3.2	25.1	23.5	100.1
201-230	23	21.1	10.9	7.5	0.7	6.7	2.7	0.7	19.5	29.8	99.6

It is evident from examination of Tables 12 and 13 that, while the number of each type of dependent clause increases in proportion to the total number of clauses used, the distribution of these dependent clauses into functional categories remains fairly constant. That is, the child at mental age 200 months uses approximately twice as many dependent clauses as he used at mental age 100 months, but roughly the same percentages of these clauses are used to express cause at both levels. Time and adjective clauses show greater variation in this regard than do any other types. This fact may be due to a real change in thought emphasis, to a changing manner of expression, or to changing relation of the topic assigned for the present study to the life interests of the children. As stated in Chapter II, clauses introduced by *when* were classified as time clauses, although frequently they suggested cause, condition, or even concession.

The reader should remember that the percentages given in this chapter are based on the total number of *subordinate* clauses only. Concession clauses, therefore, which represent at no level more than 0.7 per cent of the total subordinate clauses, include considerably less than 1 per cent (0.2 of 1 per cent) of the total clauses at these levels. In other words, one clause of concession may be found in 500 running clauses. Clauses of condition, concession, place (adverbial), purpose, and comparison all appear most infrequently when compared to the total number of all clauses used. Time, casual, adjective, and noun clauses are the subordinate types most used. Such information appears highly significant for the teaching of grammar, if such teaching is intended for functional purposes.

The findings at the lower levels may be compared with those of Boyd (3) for age nine years. He found an increase in proportion of noun clauses used from fourth to ninth years (34 per cent, third year; 42 per cent, ninth year). His is a considerably larger percentage than that found in the present study. In view of the fact that his 18 novelists use but 42 per cent noun clauses, it may be questioned whether his one child is typical. His percentage of adjective clauses is approximately the same as found in the present study for the 37 cases at 101-120 months, but his adverbial clauses are fewer.

Table 13 suggests that, if time and adjective clauses were classified more accurately as to meaning, the developing use of subordinate clauses might be found to represent a fairly constant growth in relations concepts.

B. Content of the Various Types of Dependent Clauses

Further analysis of the types of expression used is presented in the following pages by comparing sample clauses written by the children at the various mental-age levels. Samples were obtained as follows: All subordinate clauses written by the first ten children in each mental-age group were copied and each structural group assembled for purposes of comparison. All time clauses, for example, written by the children chosen from each level are presented in one series, from those written by the first child in mental-age group

101-110 months, to those written by children in the highest group. *Within each mental-age group,* however, samples are arranged according to the intelligence quotient of the writer. Because the very young children wrote comparatively few dependent clauses, all cases in the lowest group are included. The subordinate clauses for 125 of the 482 papers are thus presented. For the sake of brevity, modifiers not essential to the understanding of the sentence or clause are omitted. Faulty spelling and sentence structure are not corrected.

Distribution of the samples by mental-age groups is as follows:

Mental-age (months)	Cases
101-110	16
111-120	10
121-130	10
131-140	10
141-150	10
151-160	10
161-170	10
171-180	10
181-190	10
191-200	10
201-210	10
211-220	6
221-230	3
Total	125

TIME CLAUSES

MA	IQ	Clause
101-110	60	When school is out I will be glad.
	73	When it was time, I had to do the washing.
		When it was time to put up hay, I rake all of it.
		When my brother got kick, I had to work.
	76	When we got there I saw the mountains.
		When we got home I was surprised.

MA	IQ	Clause
	83	When it is dark I will go to bed.
		When I wake up, and
		(when I) eat my breakfast, I will go walking.
	91	When the kids come out to play * * we play.
		When I don't want to take my dog, I put my doll in.
		When I come back I take both of them.
	92	When I get there I will write you a letter.
	94	When I got home I went swimming.
111-120	76	When I get back I am going to make a garden.
	80	When you are in school you can't have so much fun.
		When you are out of school (you can have fun).
	82	I am going to work untill school startes.
	88	I stayed till school started.
	89	Wen I got home it was Saturday.
	97	When I got there I took it off.
	99	*When I get out of school I take my books and play* school.
		When my friends come to visit we play house.
	108	When summer comes I am going.
		After I am through I will play.
		I have to stay till he grow old.
		After the fun began, I played.
	108	I am going to work untill school starts.
121-130	66	When I get through I go on a picnic.
		We go three months before we start again.
	87	When you learn geography that is about traveling.
	87	I would keep house while my mother was away.
	95	When I get my work done I set down.
		When evening comes she will tuck us in bed.
		When we started into school we did not have many things.
		When school starts again mother will get our things ready.
	99	I get kercine for him while he is busy.
	99	I am glad for him while he is busy.
	99	I am glad when school is out.

MA	IQ	Clause
	107	When we got our work done he and I went fishing.
		After the two months was over we went home.
		After we got home we though we would stay.
		When we got there we saw animals.
		When the circus was over we went home.
		When we was going we had a flat tire.
		When my cousin came home he visited me.
131-140	96	Teachers are glad when vacations are, and (when) they can go home, and (then can) see their folks.
	101	When we got home it was eight o'clock.
	103	I am glad when school is out.
	104	When school was out I went on a car trip.
		While I was there I learnt to swim.
	104	I thought nothing of school but when mother asked questions.
	106	After we had a good swim we went in the spring house.
		After we got there we looked around.
		When I have a vacation I go to see some sick person.
141-150	81	A month after school started they brought me back.
	97	We played until we were ready to come home.
		When we got to H— that was where we lived.
		When the parade started my brother and I rode in it.
		When the parade was over they had riding.
		After the fair was over we went to Colorado.
		When we came home we went to S—.
	108	When I work on the farm I will husk corn.
151-160	82	Most of the pupils would quite when they are thirteen or fifteen.
		When the older folks died what would this country be?
	101	After we came out of the capital building we went to a building called Author's building.
	105	When everybody was up we began to open the presents.

MA	IQ	Clause
	106	We are working to make the best of our time until school is out.
	107	After school was out I studied for the examination.
		After she came back I had company.
		After I came back mother got my clothes ready.
	135	When I did get to play I thought it fun.
		When papa went along we would carry a watermelon or two.
161-170	85	My best vacation was when I went fishing, and
		(when) I went all over, and
		(when I) seen a lot.
	88	When I have spare time I am reading books.
	89	After school is out I help my father.
		After corn is laid by we take trips.
		After we get back there are fairs.
		We would quit as soon as we graduated.
	93	Before you would get to the summer resort you would get pleasure out of seeing things.
	94	The best vacation was when I went to visit B—.
		When we returned I wished we were just starting.
		A nice vacation was when I visited in C—.
	100	When we had the problems in school they were easy for me.
	106	When we came back we would have quite a lot of fish.
171-180	89	After school is out I go to my home.
		I spend vacation there until school begins.
		We need a rest when it gets hot.
	93	I rode it while we was there.
	94	After school is out I am at home.
		When I came home I staid for a week.
		When I returned I felt I had a nice summer.
		When a pupil tries he should have time to rest.
	99	We were watching as we drove along.
		I had a funny feeling as I left the U. S. A.
		When we got back the corn was the best.

MA	IQ	Clause
	103	They were ready when school began.
	109	I wouldn't be so tired when I have to be here.
		You can work harder when you do go away.
	114	When we got there it was raining.
		When we got out we saw a little house.
		He had belongings before he died.
		It refreshes a mind when it has rest.
	118	While I was in Iowa I was on a farm.
		When we went into the mountains we went on lookout.
181-190	97	I occupy myself until dusk comes.
		When the store is closed my parents and I take visits.
	102	When vacation opened our alfalfa was ready to put up.
		After it was up I helped feed cattle.
	106	When school is out I am anxious to get home.
		When the threshing is done we start plowing.
	117	I work while it is cool.
		When it is hot I do anything.
	119	When we got home I would work.
	123	After they left we went to C—.
191-200	102	I have a delightful time while I am there.
		It's like in spring when you feel . . .
	110	When school was closed I spent my time helping father.
		I could go fishing when I did not have much to do.
		Before school started we went to the Ozark.
	118	When I was eleven I asked to visit my uncle.
	128	The neighbors call on me to take care of children while they go some place.
		I have not time while school is going on.
		When we have vacation, after it every pupils enters school with enthusiasm.
		They were in a schoolroom when the outdoors is calling.

MA	IQ	Clause
	132	When there are violets in the timber I go to places where they are.
201-210	114	When I work I can save money.
	116	I do not have time when I am in school.
		Before I can realize it vacation is over.
	124	We would be too young when we got out of school.
		While I was there I went to a place called S—.
	125	It would be punishment to spend the summer indoors when it is so inviting out-of-doors.
	129	I go to rest before school starts.
		When I do not want to go anywhere in particular, home seems very pleasant.
	130	When my aunt comes on her vacation she takes us.
		After we come back I help my mother.
		I help my mother till school starts.
211-220	120	It is then that I read books. (Classified according to meaning.)
	123	I would spend my time there until I would start home.
		On Sunday it was about eight o'clock before I arose.
	149	While I was at home I would work in the garden.
		When it was hot I would go swimming.
221-230	136	After school was out I visited a school at T—.
		When we returned I commenced taking piano lessons.
	151	My best vacation was when I went from K— to D—.
		While we were on the steamship my father and I went downstairs.
		As we proceeded we passed the mouth of the Ohio.
	151	When I was seven or eight years old I lived in B—.

Study of the foregoing time clauses discloses a change in the content in addition to the increase already noted in the relative frequency. At the lowest mental-age level every clause is introduced by *when*. Time sense is comparatively vague. *When I wake up and eat my breakfast I will go walking* relates a series of events in temporal order. *When school is out I will be glad* suggests to the adult: *I will be glad because school is out.* The child's expression merely indicates association of the ideas, *being glad* and *having no school.* The *being glad* is not necessarily an accompaniment of the whole vacation.

It is not the province of the present study to determine whether this failure to express relations clearly (from the adult point of view) is due to inability to recognize the relations, or to lack of adequate language tools in the same sense that one may lack the name for an object which he has handled and used. A paragraph from Piaget, written as a part of his discussion of the young child's use of conjunctions, is interesting, however (27, pp. 21-22):

> "It might be claimed that mistakes such as we have been discussing are purely grammatical and have no concern with the child's thought. . . . Whether or not there is in such cases any confusion between cause and effect, or between cause and logical reason, etc., is quite another matter. What we are examing now is simply the verbal expression of causality or rather the narration of causal sequences. All that we claim is that in such narration the child is incapable of differentiating clearly between relations of causality, or sequence and of justification (however clearly he may have distinguished them in concrete observation): which means that he is incapable of assigning a fixed function in speech to each of these relations. In a word, it comes to this, that the child cannot give an account of facts."

No child in this lowest group uses a conjunction indicating exact relation as might be expressed by *after, until,* or similar words.

Half the clauses in the second unit (111-120 months) show more exact expression. A growing precision is apparent as the children develop. Occasional uses of *when* indicate generalization. At mental age 171-180 months appear four such examples: *It refreshes a mind when it has rest. We need a rest when it is hot. You can work harder when you do go away. When a pupil tries he should have time to rest.* At the two upper levels only three *when* clauses are used. Two appear satisfactory from the adult understanding. Only one, *When we returned I commenced taking lessons,* shows loose association.

CAUSAL CLAUSES

MA	IQ	Clause
101-110	60	I will be glad when school is out because I am going fishing.
	73	I had to do it (the washing) because my mother was sick.
	76	I do not like to go to school because I do not have fun.
	80	We don't have many neighbors because we only get to see them once in a while.
	80	I do not want school because I want to have a trip.
111-120	98	I want a vacation because we can go on a trip, and (because) I can go, and (because I can) stay, and (because) I can help. I want a vacation because you can ride, and you can make money.

MA	IQ	Clause
		I want to go because I want to hall water.
121-130	71	I like vacation because we can take trips.
		I like school because you can learn to spell and you can learn geography.
		People ought to have vacation because they have school.
	95	I work because my mother needs me, and because she has to work hard.
		She has to work hard for she has washing to do, and she has seven to take care of.
		My sister would wipe them (dishes) for we took turns.
	99	I do not want school all summer because I learn as much at home.
131-140	103	I wouldn't like school all time, for I go to my grandpa's.
	104	It was late, for mother was getting breakfast.
	106	We took off our coats, it was so hot.
141-150	84	I do not think any person needs school the year around because nine months is enough, and it is too hot.
	97	We rode them because it was only eleven miles.
		Our man almost got killed because a horse fell on him.
	108	I like vacation because I learn things, and I study birds.
		I can swing because I live on a farm.
		I do not want to go to school because we get tired, and (because) we like to see our cousins.
151-160	105	We had to go on the train for the car was loaded.
	108	I like vacation because you may see wonderful things.

MA	IQ	Clause
161-170	85	It isn't necessary for the pupil wouldn't get vacation.
		The only ones are the teacher for they could get more money.
	88	Twelve months is too much because the students would not have no outing, and
		(because) they would have school on their minds all of the time.
	89	I like these trips because I can see the country, and
		see how people farm, and
		see how much difference there is.
		There would be no pupils because we would quit school.
	94	I wished we were just starting, for it was near time for school.
	96	We should have eight months school because vacation passes quickly.
	100	I do not think it right because we would have too much study, and
		we learn as much in nine months, and
		you learn a lot on trips.
171-180	89	I don't approve of school twelve months because I think we need a rest.
	103	I am going to have my brother show me, as he teaches there.
	109	Vacation is necessary, for it gives you time to rest.
	114	We should have nine months because it refreshes a person.
	118	I think this, because it would give us much vacation.
181-190	100	I don't think we ought to have school because I need the time.
	102	The pupils would not be for it because they would get stale, and

MA	IQ	Clause
		because they would not study so hard.
	110	I take music lessons in summer for in the winter I have school.
		I take lessons in summer for "all work and no play makes Jack a dull boy."
	117	School shouldn't run (in summer) because everyone gets tired.
	119	I worked as we run a dairy.
		It is not good because it gets so hot.
	141	I wouldn't like school all the year because it would be so hot, and
		because all work and no play makes Jack a dull boy.
191-200	105	It would be unfair because they can't do their best.
	106	School all year is a bum idea, because one's mind gets dull, and
		he forgets everything, and
		a person wouldn't learn.
	109	I was interested because I had never seen them before.
	111	I learned for I have actual experience.
		They gain in knowledge because they have access to plants.
		I do not feel my vacation wasted, because I learned about cooking.
	118	As I live in a small town, I love to spend my vacation in cities.
201-210	114	It is fun to pick cherries because you can eat, and you can earn money.
	116	I practice as it is my ambition to become a good player.
	124	Shorten the year, for you remember . . .
	139	Beings as I live on a farm, I have good times.
211-220	123	I do not believe in more than nine months because many children have to work, and

MA	IQ	Clause
		because they would have to quit school.
	133	I am glad that we don't have school. (Classified according to meaning rather than structure).
221-230	151	This was enjoyable as we saw the country, and we crossed the Mississippi. As I am supposed to write I will give my experience.
	151	I do not count last summer's vacation lost because I have become acquainted with a life totally different.

Structurally the causal clause appears to offer little difficulty to these 482 children. With two or three exceptions, the causal clause follows the independent (result) statement. As one might expect, the relations expressed are very closely concerned with the children's own experiences. In few cases is there any attempt to generalize. *I like vacation because I take trips. I can swing because I live on a farm,* and *I practice as it is my ambition* are typical. The limitations of the assigned topic may in part be responsible for the fact that the causes given are chiefly causes for the children's own feelings. Such "reasons" fall into what Piaget (27, p. 608) calls an intermediate class, between relations of cause and of effect, and logical relation. There is a slight tendency toward broader understanding at the upper levels. *As* and *for* are adopted as conjunctions, supplementing *because,* which alone suffices up to 131 months.

Conditional Clauses

MA	IQ	Clause
101-110	69	If we have to go to school there will be lots of these * * .
	79	If they were busy I would help.
111-120	82	If you go to school you cannot make money.
121-130	66	If we don't have vacation we won't get off for anything.
	69	If we have three months I will get to go.
		If we have to go twelve months I won't get to.
131-140	106	The spring house was as cold as if there had been ice there.
141-150	84	If you are going to go to school I think you ought to get vacation.
	86	If a kid does not have vacation he will not built up his body.
	93	If we worked all the time we would not be healthy.
		If we keep our mind going it would get very tired.
	108	We would not have time (for play) if we had school.
	122	If I got so many orders I got a prize.
151-160	82	If we have twelve months I am at the age where I can quit.
		If we had school twelve months there would be a lot of children that would not have books.
	82	What would this world be if there were none of the young folk around.
		If we had school the year around most of pupils would quit.
	135	If I did not do this I would go.
161-170	89	If we went the year around we would get tired.
	93	If you had a great distance to travel you would get enjoyment.

MA	IQ	Clause
		You would get enjoyment if you were going to Yellowstone.
	94	If we had to go twelve months I would get tired.
	96	If we went the year around we would forget how to play.
		If we had school the year around there would be a lot of people quit.
	100	If we had school we would have to be worrying.
		If we were not going to school we would have a rest.
		If we shouldn't have a vacation why do employers let their helpers have vacations?
171-180	103	If they have a vacation they are ready for school.
	109	If you don't go to school so long you like it better.
		If you went to school all year you wouldn't be as healthy.
	134	The parents would be more willing if we only went nine months.
181-190	102	They wouldn't study so hard as if they had nine months.
191-200	105	If I have to go twelve months I quit.
	110	If a person thinks we should have twelve months he does not know.
	111	I wouldn't have learned if I had been attending school.
		They would not take these trips if they were in school.
	128	If they make us go to school all year we will get tired.
		If they were cooped up in a hot schoolroom, they wouldn't * *.
		If they make us go in summer time we will have no time for sports.
	137	If anyone opposes this idea, I do.

MA	IQ	Clause
201-210	116	If we were to have school continually, students would become tired of it.
	121	If you read out of a book it is just taken as commonplace.
	124	If you do not think so, just try it.
		If you would have school twelve months the students would go on a strike.
		If you had school twelve months, the students would get tired.
	130	I don't know what my mother would do if I never had vacation.
	139	I learn more than if I went to school.
		If we didn't have at least three months vacation we would get tired.
		If you want to do something, shorten the year.
211-220	123	If they had twelve months of school, they would have to quit.
221-230		No conditional clauses.

Conditional clauses appear to change little in quality, but to increase in gross (not relative) frequency. They offer no structural difficulties inherent in their specific nature, if the examples here presented are typical.

CONCESSION CLAUSES

MA	IQ	Clause
121-130	98	I have to work if I *am* a girl.
151-160	135	I thought it fun even if I only had five or ten minutes.
181-190	117	I have a good time, while at the same time I make money.
201-210	114	Although it is hard I would rather do that.

If the compositions in this study may be taken as typical, the use of concessive clauses is very rare with children at the levels studied, since 125 children, writing approximately 17,000 words, use only four concessive clauses.

CLAUSES OF PLACE (ADVERBIAL)

MA	IQ	Clause
141-150	81	This is where I had my fun.
151-160	101	I have went picknicking where I would go swimming and (where I would) have a good time.
181-190	97	It is hot everywhere one goes.
	106	We plow where the oats was.
191-200	109	I was around where they lived.
201-210	129	I go where I choose. I plan to go where I hope to see many new things.
211-220	136	We went where we learn to put up tents. I visited where my cousin went.

The relatively small number of adverbial clauses of place should not be interpreted as meaning that the child seldom expresses ideas of place by means of a clause. Many *place* clauses are, however, adjectival. The children in the present study seem to prefer to use the latter form.

PURPOSE AND RESULT CLAUSES

MA	IQ	Clause
101-110	69	I work so I can buy books, so I can go to school.
111-120	88	I put them in water so they will keep. You can make money so you can go to C—, and pay your own way.

MA	IQ	Clause
	109	We were so full that we couldn't walk. We are so empte we want an apple.
141-150	84	I like to find where animals are so I can trap them. I want vacation so I can make money.
161-170	106	It would be better to have vacations so we could have a little fun.
171-180	89	It gets so hot that you can hardly sit in school.
	93	I get so interested that I cannot stop.
	103	It gets to hot they get tired. It gets to hot they can't do good work.
	104	It would be so hot that the students would not study.
	114	They had us sign our names so they would know. I got away from H— so I wouldn't be so tired.
181-190	117	It is so hot that it would be unpleasant.
	119	It gets so hot that you could not study.
201-210	121	Swimming in summer might make you such an expert that you would save many lives.
	139	We would get so tired we would be disgusted. We would get so tired we wouldn't do our best work.

The foregoing cases are too few for generalizations. It may be noted, however, that the nine examples prior to mental age 161 deal with individual purposes or specific results actually experienced. Ten of the thirteen clauses above that level are fairly general statements. No difficulties with structure peculiar to purpose and result clauses are apparent.

CLAUSES OF COMPARISON

MA	IQ	Clause
101-110	69	I work harder than you wood expect. I work hard than you every did. I do harder thing than you think.
121-130	95	My big brother and sister helps more than we little ones can.
131-140	104	It was later than I thought it was.
141-150	93	We need rest as well as we do school work. We like to have more vacation than we do at Christmas.
151-160	135	I did not go for a trip as most people do.
161-170	96	We need play as well as we need work.
171-180	99	We went as far as our road would take us.
	103	I learned more that summer than I ever did in one summer.
191-200	137	I got more good than I could have at school. I spent my time learning things more interesting than I ever did at school.

Even the few clauses of comparison here presented indicate that their use offers difficulties to the grade-school pupil. The child fails to make the comparison complete in so far as comparable structure is concerned.

NOUN CLAUSES

MA	IQ	Clause
101-110	60	I think that I am going to my sister.
	69	I want you to know that it will be so hard.
	80	I no I will have a good time.

MA	IQ	Clause
	85	I think we are going to do it this summer.
	91	I thought I would try it again.
		They say they'll take it.
		You think I do.
	102	She said her mother said that you could come to visit me.
111-120	80	I think it is fun to play Indian.
	89	His mother told me John was to H's house.
		Miss K. said that the boys were down to the farm.
	98	I think I would not go to school in the summer.
	102	I hope that I will get to go.
	108	What do you think I saw?
	109	Then we play that it is stuck.
121-130	66	I think we should get off.
	69	*I think I am going on a trip.*
		I think that is a foolish idea.
		Our teacher and Mrs. G. think we had ought to have a vacation.
	87	It seems that people ought to have vacation.
	99	I am glad to tell you about what I do.
	107	We thought we would stay.
		We thought we go see the circus.
		No one knows where he is at.
131-140	83	I think we should have 9 months school.
	104	I got up to see if I could find something to do.
		I thought it was.
	104	We thought two cars were going across and hit him.
		She said he was at the station.
		I played I was the mother.
		I went to see where they pump the oil.
	113	Some negro's said I was a mechanic.
141-150	84	I like to find where animals are.
		I do not think any person needs school the year around.

MA	IQ	Clause
		I think you ought to get vacation.
		I think you had just ought to haft to go four days a week.
	86	I think that a kid should have some pleasure.
		I think that he will not build up his body.
	93	I learned to do what I ought to do.
		I think we should have vacation.
		There is a saying: All work and no play makes Jack a dull boy.
		I think this could apply to us.
	108	I think I will go to N—.
	108	I think we should have eight months of school.
		I think we ought to have vacation now.
151-160	82	I mean that they would be used up.
		(I mean) the pages are out of places.
	86	I do not think we should have twelve months of school.
	90	There is a motto, all work and no play makes Jack a dull boy.
	101	There was the story of what their occupation was.
		That is how I spend my vacation.
	135	You may think I am making something up.
		I would go and see if some cantelopes were ripe, or if melons were ripe.
161-170	85	I do not think it is necessary to have 12 months school.
	88	I think twelve months is too much.
	89	I can see how people of other states farm, and how much difference there is in Kansas and Colorado soil.
		We see how they water their plants.
		I believe we would get tired.
		I am afraid there would be no freshmen.
	94	I think I would get tired.
	96	I think we should have eight months school.
	100	I don't think we should have school all the year.

MA	IQ	Clause
		I do not think it is right.
	106	I believe it would be better to have vacation.
171-180	94	I think I can go visiting.
		I felt that I had a nice summer.
		What I think of twelve months of school is that we should have time to rest.
	103	What I think is that children should get a rest.
	104	I think I could learn more that way.
		I learn how they live.
		I get to learn how they raise crops.
	109	I think vacation is necessary.
	114	I think we should have nine months.
		They would know how many had been there.
	118	I think I would like it better.
		I hope we have this condition some day.
	134	I think we should go only nine weeks.
		The reason is because nine months is enough, and we cannot study in summer.
		I think parents would be willing.
181-190	97	It is said that hardly no person can study * *.
		It is said that hardly no person can get anything from it.
	100	I don't think we ought to have school.
	110	I think you can learn lots of things.
	117	I think school shouldn't run.
	119	I think it is a rotten idea.
		I think the idea is not good.
	140	I hope I have another summer like this.
		My reason is that we ought to have more time.
191-200	102	I want what a person would call a vacation.
		People ask me: I don't know what you do.
		I don't know what you do.
		I don't think we ought to go to school.
	105	I think it would be unfair.

MA	IQ	Clause
	106	I said school all the year is a bum idea.
	109	I work at what I like.
	110	I think he does not know.
		If a person thinks we should have twelve months * *.
		He does not know what it is to go.
	111	I do not feel that my vacation was wasted.
	137	I think I got more good from that.
		I do not think people spend their time doing things.
201-210	121	Mountains are good examples of how one becomes educated.
	124	I think that is a good way to spend a vacation.
		You think that is a good way.
		I think the students would go on a strike.
		Another reason is that it would be too warm.
		You must remember: all work and no play makes Jack a dull boy.
	125	I can say that it would be punishment.
	130	I don't know what my mother would do.
	137	It has been said we might go twelve months.
		I think we should only eight months.
		I do not think it would be fair.
		I think that half of the year ought to be vacation.
		It has been said: All work and no play makes Jack a dull boy.
211-220	120	I found that I would be a delegate.
		I think my most interesting vacations have been in Colorado.
		I think vacation should be a time for recreation.
		I think this is an exception.
		I think we need vacations.
		(I think) few of them are ill spent.
		I hope that twelve months school will never come.
	123	I finished what I had to finish.
	123	I neglected to say that I arose at six.
221-230	136	I believe I spent a profitable summer.

MA	IQ	Clause
	151	I believe a nine months school term is sufficient.
	151	I do not think there ought to be school all the year.

Uses of the 133 noun clauses here listed are distributed as follows:

A. Direct object of verb		
1. Following some form of *to think*	64	
2. Following a verb of saying, knowing, or believing	21	
3. Following all other verbs	29	
		114
B. Used nominatively		
1. In apposition	11	
2. As subject	2	
3. In predicate after *is* or *seems*	3	
		16
C. Used as object of preposition		3
	Total	133

Boyd (3), in commenting on the fact that his child used a large percentage of noun clauses (34 per cent of all subordinate clauses at age nine), says:

> "Perhaps the explanation is to be found in the fact that it is generally words like 'say,' 'think,' 'ask,' and others of kindred meaning that lead on the 'that' or the 'what' of the noun clause."

His explanation appears valid in the light of the foregoing summary, which shows 85 of the 133 noun clauses objects of such verbs as Boyd suggests.

Although noun clauses constitute over 20 per cent of the total number of dependent clauses, in none of the examples quoted is there any evidence of difficulty in managing structure. No marked change in type or content of clauses with increasing age is evident from the examples given. This finding is of interest in view of the argument often presented for the teaching of noun-clause analysis, that it assists pupils in development of correct habits of sentence structure.

ADJECTIVE CLAUSES

MA	IQ	Clause
101-110	69	The boy that live in the country have to work.
		The one that live in the city sit around.
		They will be a lot of these what won't go.
	80	The trip I am going to make is to Idaho.
111-120	82	That is the reasent I do not want school.
	82	I am going to B— on the farm that I live on all my life.
	85	We stopped at O— where my uncles lived.
	98	The vacation I am going to make is to C—.
	99	We have subjects the way my teacher has them.
		That was all I did.
	111	I saw my brother who had just come.
	127	They had a little girl that would play with me.
		There was a woman that I sat by.
121-130	66	There are not many trees like you see around here.
	95	The first year we came here my mother started washing.
	98	They bring things they grown.
	99	I go on errands for women who are not able to go.
		I play with the girl who lives in the next house.
	107	We had a flat tire that took us half an hour.
		We called the place we thought he would be.
131-140	61	We went to the country where my uncle lives.

MA	IQ	Clause
	101	The one that is my age, her name is K—.
		The first day I was there we went for a ride.
	103	I am going to a ranch that my father has rented.
		I go to my grandpa's who lives in D—.
	104	The camp was by a lake which I went swimming in.
		I had the most joyful summer I had had before.
	106	They wanted to go on a trip which was a short trip.
		We went to a pond that covered an acre.
		We went in the house that was cold.
141-150	81	I stayed at places where I used to live.
	93	I learn to do things that I will need to do.
		The thing I learn to do was * *.
		There is a saying we could go by.
	97	We went to the place where they kept their horses.
		There was a boy from W— that rode.
	108	I will go boatriding in the canoe I am making.
	122	I took orders for the J. H. magazine that comes every month.
		It comes to the people that take it.
		I had a little garden that I hoed.
151-160	86	I studied for exams which took a lot of my time.
		I was helping mother what time I was not doing that.
	101	*In the museum that I went to,* I went to a room.
		I went to a room that I saw a statue.
		This that I told you about was this last vacation.
	105	The best vacation that I ever had was the Christmas vacation.
		The first present I got was a knife.
		That was the best vacation I ever had.
		The way I spent my vacation was helping.
	106	There would be a lot of children that would not have books.

MA	IQ	Clause
		I am at the age where I can quit.
	108	I am going to see my sister which works in B—.
		I go to play with girls that live there.
161-170	85	The thing I like to do is travel.
		The pupils who attend wouldn't get vacation.
		The only ones that want twelve months of school are teachers.
	88	It is alright to have school for those who want to go.
	93	I would like to spend my vacation in a resort for which you would get enjoyment out of.
		You would get to the resort where you were going.
	94	The best vacation I ever had was * *.
		I went to visit my aunts who live in S—.
		I went to a show which interested me very much.
		Another nice vacation I had was * *.
	100	I learned about figures like we have in problems.
	124	I take piano lessons which takes two hours.
		We have plays that I like to be in.
171-180	89	I go to the hills that are just a few miles from our place.
	93	I go to the shows we have here.
		I played with the boy that lived next door.
		We had my brother help care for a family that went to I—.
	94	We had company which made it better.
	99	It is one of the most beautiful places I have seen.
		At this town was a mine of which I viewed.
	103	The last vacation I had was two years ago.
	109	I took lessons which gave me something to do.
		I made a headband which I had to have.
		I had it for campfire which I belong to.
	114	We were climbing everyplace we could.
		At the side where we packed was Buffalo Bill's grave.
		This house that was of logs was built for him.
		It had his belongings that he had.

MA	IQ	Clause
	118	The way it is we have too much school.
	134	We started home where we arrived at midnight.
		We arrived the second week that we had been on our way.
		The reason I think so is * *.
181-190	102	They would get stale as you might say.
	106	I commenced work which I enjoyed at first, and which got more tiresome.
	110	I relieved mother of work which I don't have time for during school.
	117	Each day when the weather is fit I work.
		I have seen many things that is educational.
	140	I entertained a society I belong to.
191-200	102	The three months I have I spend on a suburb.
		One place I manage to go is my cousin's.
		I help people the best way I know how.
	106	We saw the place he was.
		We saw the lake where part of it flowed to the Pacific.
		He forgets everything he knows.
	109	I went to visit my relatives who live quite a way from here.
		I went to the city that they were close to.
		It was the first time I had saw them.
	111	I learned more than I wouldn't have learned.
		There may be some who waste vacations.
		Boys and girls who spend their vacations on the farm gain in knowledge.
		Those who take trips learn by seeing.
	118	One thing which stands out in my mind is a trip.
		I learned many things which would be impossible to learn at school.
	128	I do art work which I do not have time to do during school.
	132	I go to places where they are.
		There are places where I can go swimming.

MA	IQ	Clause
	137	Pupils spend their time doing things that will help them.
201-210	114	You can eat all you want.
	116	I spend my vacation at home, which is in the country.
		The spare time I have I listen to the radio.
	116	I try in the vacation that we have * *.
		I have friends that live in the country.
	121	You can learn things which you would never learn at school.
		This leaves an impression which you will not forget.
	124	I and all the other scouts who went along learned useful things.
	125	The only chance a pupil gets is during vacation.
		Three months is short as it is now.
	129	I learn things which are helpful.
	137	Instead of having school twelve months, as has has been said, I think eight months.
	139	I have all the good times that are possible.
		I have to help which is better for health.
211-220	120	It is that time which I read books.
		I have been interested in the things it does.
		The beauty of the scenes which I saw inspired me.
		The beauty inspired me to higher ideals than those which could be obtained from books.
		Many sights which I saw have been subjects of themes.
		I read books which cannot be read during school time.
		I delight in the amusements D— has to offer.
		The mountain trips were the most wonderful experiences I have ever had.

MA	IQ	Clause
	121	I studied piano which necessitated three hours of practice a day.
	126	You can earn money to by the things you want. You can do the things you would like to do. You can read all the books you want.
	136	I lived in a neighborhood where there were a number of children.
221-230	151	Those who have an opportunity to visit different places cannot help but benefit. I have become acquainted with life totally different from anything which I was familiar.
	151	There were 40 cars and the people whom they belonged to. *At the bank where we put off were many ferries.* We looked at the engines which were very large. The distance was six miles by the way we went. The engines were strong considering the load it had on.

The percentage of subordinate clauses in this study used adjectively doubles from mental age 101 to 230. The relations expressed are too varied to permit generalization as to the nature of thought expressed. Restrictive and non-restrictive clauses both appear early (mental age 111-120) and are found at most mental-age levels. Restrictive clauses, however, predominate.

Of interest to teachers are the structural difficulties which adjective clauses, judged by these examples, offer pupils. *I had the most joyful summer I had had before. I went to a room that I saw a statue. A resort for which you would get enjoyment out of* are examples. Evidently the child has difficulty in holding the dual function of the relative in mind.

C. LENGTH OF CLAUSES

As was stated in Chapter I, studies of language development of preschool children have frequently emphasized the changing proportion of the various parts of speech. In the present study complete predicates instead of verb-words have been counted. The reader should remember this, since a predicate often contains several words, as in the clause, *I have been working.* Table 14 presents the average number of words and the number of predicates per theme and also the average number of words per predicate or clause. Examination of column 4 reveals an insignificant variation in the number of words per clause. Apparently *the manner in which the clause is used*, and the exactness of the relations within the clause, determine the value of

TABLE 14

AVERAGE NUMBER OF WORDS PER THEME, NUMBER OF PREDICATES PER THEME, AND WORDS PER CLAUSE, IN COMPOSITIONS WRITTEN BY GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, IN THREE KANSAS SCHOOLS

MA (months)	Number of cases	Av. no. predicates per theme	Av. no. words per theme	Av. no. words per clause
101-110	16	15	113	7.5
111-120	21	17	124	7.3
121-130	37	21	138	6.6
131-140	42	22	144	6.5
141-150	45	18	126	7.0
151-160	80	17	125	7.3
161-170	72	18	137	7.6
171-180	64	19	145	7.6
181-190	49	17	140	8.2
191-200	33	21	159	7.7
201-210	14	19	159	8.4
211-220	6	15	131	8.7
221-230	3	29	231	7.9

the expression. The relative number of verbs used is, by inference, fairly constant above mental age 101 months.

D. INFINITIVES

As was indicated in Chapter II, an additional study was made of infinitives. These were divided into two general categories. In the first were included those infinitives which are combined with a finite form of *be* or *be going* to indicate future time. Smart illustrates this use as follows (30, p. 179):

> "He *is to be* here next week.
> "I *am going to do* the work tomorrow.
> "He *is about to begin* his speech."

Because in such cases the infinitive functions merely as a verb and is combined with a finite auxiliary, it has been included already in the present study in the record of predicates. These infinitives indicative of future time appear in half the finite predicates at the lowest mental-age level (101-110 months), and in only one in eight or nine at 191 months. Particularly popular with the younger children is the expression *I am going to go,* a fairly vague statement comparable to the *when* clauses of the lower levels.

Other uses of the infinitive, combining the functions of the verb and those of noun, adjective, or adverb are included in the second category. Of particular interest is the frequent use of the infinitive to express purpose, as in *We went to X— to see our friends.* This appears a frequent form of expression with the younger children. Infinitives as objects of verbs clearly perform predicate functions as in *They asked me to go* (asked that I go). Table 15 gives the number of infinitives (exclusive of those complementary infinitives just discussed) in comparison with the number of *subordinate* predicates. Comparison is made with dependent predicates because the infinitive is *per se* dependent.

TABLE 15

NUMBER OF SUBORDINATE PREDICATES AND OF INFINITIVES (EXCLUSIVE OF THOSE USED WITH FINITE FORM OF *Be* OR *Be Going* TO INDICATE FUTURE TIME) USED BY GROUP A, 482 CHILDREN IN GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

MA (months)	Number of cases	Number of subordinate predicates	Number of infinitives*	Ratio of subordinate predicates to infinitives
101-110	16	40	32	1.25 to 1
111-120	21	54	41	1.3 to 1
121-130	37	181	118	1.5 to 1
131-140	42	191	115	1.7 to 1
141-150	45	209	116	1.8 to 1
151-160	80	393	159	2.5 to 1
161-170	72	438	204	2.1 to 1
171-180	64	379	177	2.1 to 1
181-190	49	262	136	1.9 to 1
191-200	33	213	77	2.8 to 1
201-210	14	94	28	3.4 to 1
211-220	6	31	13	2.4 to 1
221-230	3	22	8	2.7 to 1
Totals	482	2507	1224	

* Not including those combined with finite form of *be* or *be going* to indicate future time.

Examination of Table 15 discovers a gradual but decided decrease in the use of infinitives when their incidence is compared to that of dependent verbs. Whereas the younger children use an infinitive for every one and one-fourth (1¼) dependent predicate, the older ones use one infinitive to every two or three such clauses. Here again appears evidence of growing exactness in the expression of relations.

SUMMARY

While dependent clauses increase in frequency with increasing maturity of the writers, they also increase in complexity and clarity of thought. Increase of subordination is paralleled by increasing exactness in the use of connectives.

Children learn gradually to use all recognized forms of dependent clauses. The larger number of these types apparently offer no structural difficulties inherent in the kind of clause, if one may judge from the lack of structural errors found in this study. Adjective and comparison clauses are exceptions.

While many clauses change in character (from independent to dependent) with increased mental and chronological age of the writers, the average length of the clause (proportion of predicate to other words used) is comparatively constant between the ages of eight and sixteen. The change in quality is consequently due to change in relation and content of clauses.

The proportion of infinitives to subordinate predicates decreases with increasing maturity of the writers.

V

ANALYSIS OF THE WRITING OF GROUPS B AND C

In order to determine the degree of subordination to be expected from individuals more mature than those in Group A, the writing of Group B (504 high-school students) and of Group C (21 eminent psychologists) was studied.

GROUP B

Reference to Table 16 shows that the median chronological age for each mental-age level in Group B approaches 192 months, or 16 years. Since *The Terman Group Test of Mental Ability* is standardized on the assumption that mental development ceases at about year 16, it seemed best to attempt no detailed analysis

TABLE 16

DISTRIBUTION OF MENTAL AGES, WITH CORRESPONDING MEDIAN CHRONOLOGICAL AGES, FOR GROUP B, 504 PUPILS FROM LEAVENWORTH AND LAWRENCE (OREAD TRAINING), KANSAS, HIGH SCHOOLS

MA (months)	Median CA (months)	Number of cases
121-130	192	1
131-140	185	2
141-150	187	10
151-160	187	17
161-170	191	58
171-180	186	80
181-190	186	99
191-200	192+	106
201-210	192+	68
211-220	192+	39
221-230	188	16
231-240	191	8

TABLE 17

Distribution of Indexes of Subordination Found in the Writing of Groups A and B

Index	Frequencies	
	Group A	Group B
0- 4.9	40	6
5- 9.9	26	5
10-14.9	35	14
15-19.9	47	26
20-24.9	61	52
25-29.9	64	65
30-34.9	61	83
35-39.9	39	53
40-44.9	44	71
45-49.9	23	44
50-54.9	22	51
55-59.9	8	15
60-64.9	8	12
65-69.9	2	3
70-74.9	2	4
Totals	482	504
Median index	27.5	35.09
Mean index	28.0	36.15
Sigma	±15.30	±13.25
Difference of the means,	8.15	
Sigma of the difference,	±0.91	

by mental-age groups, but to treat the 504 cases as a unit.

In Table 17 are shown distributions of subordination indexes for Groups A and B. Although both groups include ninth-grade pupils, a clear difference between tendencies toward subordination exists. The mean index for Group A is 28; for Group B, 36.15. The difference between the means is 8.15. Using Garrett's formula[4] we find the sigma of the difference between means to be 0.91. The difference, which is ap-

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[4] Garrett (11, pp. 128-129):

$$\text{Sigma}_{\text{diff.}} = \sqrt{\text{sigma}^2_{(\text{av. 1})} + \text{sigma}^2_{(\text{av. 2})}}$$

proximately nine times this value, may be accepted as statistically real.[5]

More detailed comparisons may be made. The highest median index for any mental-age unit in Group A appears at 161-170 months (see Table 8, Chapter III). Indexes for units above this, as suggested in Chapter III, apparently are lowered because the pupils represented are all superior mentally and correspondingly low chronologically. Median index at this level (161-170 mental months) is 33.2 (mean, 33.5).

In Group B, indexes for mental-age units from 161-170 to 211-220 months, inclusive, vary only between 35.5 and 36.5. The higher index at 161-170 months (mental age) for Group B may be explained by the fact that chronologically it is 16 months older than the corresponding unit in Group A.

Attention is called to Table 10, Chapter III. One small group, 23 cases, of pupils over sixteen years of age (chronologically) has a median index of 36.25 and a mean of 36.6. Figures for Group B, with the large proportion of cases at this age level or above, confirm the reliability of this Group-A finding.

It appears from the foregoing that approximately 36 per cent of the clauses used by high-school students sixteen years of age or older are subordinate. Conversely, the percentage of dependent clauses used in writing increases until age sixteen or above. Data in the present study suggest that high intelligence quotient does not greatly hasten this use of complex structure. The 24 students in Group B (see Table 16) with mental ages 221 months or above constitute a high intelligence group, with no intelligence quotient below 115. Chronologically, they are two months younger than the average individual in Group B. The median index for these superior individuals, however, is only 32.8, in comparison with 36.15 for Group B as a whole.

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[5] Garrett (11, p. 133): "It is usually customary ot take a $\frac{D}{\sigma_{diff.}}$ of 3 as indicative of complete reliability, since —3 includes practically all of the cases in the 'distribution of differences' below the mean. A $\frac{D}{\sigma_{diff.}}$ greater than 3 is taken as indicating just so much added reliability."

TABLE 18

SUMMARY OF DATA FROM ANALYSIS OF THE WRITING OF GROUP B, 504 PUPILS FROM LEAVENWORTH AND LAWRENCE (OREAD TRAINING), KANSAS, HIGH SCHOOLS

Number of cases		504
Number running words		82,662
Total number predicates		
In independent clauses	6,627	
In dependent clauses	3,708	
In all clauses		10,335
Average length of theme, words		164.0
Average length of clause, words		8.0

Table 18 summarizes the data for Group B. Compositions total 82,662 running words, and include 3,708 dependent and 6,627 independent predicates. The papers are longer than those written by the younger children in the same length of time, and average 164.0 words. Clauses average 8.0 words, approximately the same as those written by children of mental age 180 months and above (see Table 14), Group A, and only approximately two words longer than those written by children at the lowest mental age studied. Apparently length of clause is not a significant measure of language development for children in Grades 4 to 12, inclusive. In contrast to this statement should be noted the discussion concerning length of the clauses found in the writing of Group C (see Table 19).

While ratio of dependent to independent clauses is indicative of complexity of structure, further analysis is desirable. The pupils in Group A use 2,507 dependent clauses. Of these, all but 214 are attached to the main clause directly. The 214 exceptions are dependent upon other dependent clauses. In contrast, papers from Group B contain abundant examples of involved hypotaxis. The following sentences chosen from consecutive papers on one mental-age unit illustrate:

I think that the plan which is being used is about as good as it could be. (Boy, MA, 187 mos.; CA, 176 mos.)

I like this book because almost any book I read has to be an adventure. (Boy, MA, 187 mos.; CA, 176 mos.)

I pleased him so much that he told me when I left that if I wanted to work this summer I could have my job back because he wanted to help me through school. (Boy, MA, 188 mos.; CA, 192 mos.)

In order to clarify the comparison, samples are here presented from papers written by Groups A and B. The first complex sentence in the writing of each mental-age unit is used. The comparison is significant in a consideration of the problem of teaching grammar and sentence structure in the grades and high school.

MA	CA	Group	Sentence
101	121	A	When it is dark, I will go to bed and sleep.
		B	(No cases at this mental-age level.)
111	125	A	When I got there it was Saturday.
		B	(No cases at this mental-age level.)
121	127	A	I work most of the time because my mother needs me, and because she has to work hard.
	192+	B	The most interesting trip I ever had was the trip to St. Louis, Missouri.
131	148	A	My cousin lives in town but we went to the country where my uncle lives.
	187	B	*I am going to tell about my good time that I had when I went out to our farm where I used to live with a bunch of girls.
141	145	A	We went to the place where they kept race horses.
	174	B	*For my opinion I would suggest that we do not have a twelve month school session because in the summer time it is so hot and most of the people want to get a steady job, but if you were going to school all time you wouldn't get the chance to get as much fresh air as much as possible.
151	149	A	The way I spend my vacation is by going on trips.
	192+	B	In the evenings after I was through I would go swimming at the Y. M. C. A. or play tennis.
161	107	A	I think we should have eight months school and four months vacation.
	192+	B	*The kind of books I enjoy reading most are those which are full of adventures of life, those which, when reading carry me along fast

MA	CA	Group	Sentence
			in thought, so that I will be always interested in the book.
171	173	A	It is one of the most beautiful places I have ever seen.
	192+	B	I like to read books by Jack London about the far north in Alaska, and dogs which were used to pull the sleds, how the dogs were treated.
181	128	A	I entertained a little missionary society I belong to.
	177	B	*I think we should have at least three months vacation, because if we had school twelve months a large number of students would get tired of going and quit school.
191	181	A	We went to Wisconsin first, then to South Dakota and we saw the President and the place he stayed.
	192+	B	I suppose it is human nature to enjoy books with a happy ending and to have the main people have strong character.
201	151	A	*I think that instead of having school twelve months of the year, as has been said we might, I think we should have only eight months of school and four months of vacation, or more months of vacation and less school than that.
	192+	B	I believe that I had my most interesting experience summer before last.
211	173	A	I studied piano, pipe-organ and voice most of this summer, which necessitated three or more hours of practice a day.
	174	B	The books I like to read best are books about boys my own age.
221	159	A	I spent my vacation at home last summer and I'm sure I spent a profitable vacation.

MA	CA	Group	Sentence
	185	B	The most profitable vacation I ever had was back in 1928.
231	—	A	(No cases at this mental-age level.)
	188	B	We clambered into the small coach, and had just gotten ourselves settled when we heard the cry of "All aboard."

Sentences in the foregoing which contain subordination-on-subordination are indicated by stars. Of the 13 sentences written by Group A, only 1 contains this secondary subordination. On the other hand, 4 of the 12 samples from Group B contain clauses depending upon other dependent clauses. The growing complexity of structure here illustrated may explain in part why formal grammar presented in the eighth, or even in the ninth, grade fails to affect later writing. At the time when instruction is given, the pupil, even if he should by chance comprehend the abstractions taught, does not have within his own writing experience sentences to which many of the principles of grammar apply. Later, when he himself begins to write such sentences, he does not make the application unless the principles are presented a second time.

GROUP C

Group C, as explained in Chapter II, consists of 21 psychologists, contributors to *The Psychologies of 1930.* Approximately 600 running words, consisting of two 300-word samples, were analyzed for each writer. It is acknowledged that the carefully constructed prose of these experienced writers is in many ways not comparable to the rapidly written composition of the children whose writing forms the basis for this study. Analysis of these Group-C samples is offered to furnish further data as to the probable trends in subordination used in mature writing and thinking.

TABLE 19

SUBORDINATION INDEXES OF INDIVIDUALS IN GROUP C, 21 EMINENT PSYCHOLOGISTS; TWO SAMPLES FOR EACH

Psychologist	Index on first sample	Index on second sample
a	17	21
b	20	46
c	23	44
d	30	33
e	37	55
f	39	39
g	40	38
h	41	37
i	41	43
j	43	33
k	45	50
l	47	57
m	50	40
n	50	44
o	52	50
p	52	55
q	53	52
r	55	39
s	61	57
t	64	59
u	70	66
Mid-score	41	44

Rho, 0.61

Inferred *r* (Pearson product-moment coefficient), 0.628±.093

Table 19 presents the indexes for each of the 21 psychologists on each of the two samples. Individual scores appear here according to rank of subordination index on the first sampling, and not in the order in which the writers' contributions appear in the book. Although considerable variability appears, only 12 of the 42 indexes fall below 40, and only 7 below 35. Those whose indexes are high on the first sample tend to be high on the second, and vice versa. Correlation by the method of rank differences[6] gives a coefficient of 0.61, inferring a Pearson product-moment coefficient of 0.628±.093 (11, p. 192).

TABLE 20
DATA FROM ANALYSIS OF WRITING BY GROUP C, 21 EMINENT PSYCHOLOGISTS: NUMBER OF WORDS, OF INDEPENDENT AND DEPENDENT PREDICATES, OF WORDS PER PREDICATE, AND THE SUBORDINATION INDEX, ALL FOR EACH SAMPLE

	First sampling	Second sampling	Total
Number of samples	21	21	42
Total words per sample	*300*	*300*	*600*
Total number of words	6,300	6,300	12,600
Number independent clauses	223	225	448
Number dependent clauses	185	196	381
Total number clauses	408	421	829
Subordination index for group	*45.3*	*46.5*	*45.9*
Average length of clause (words)	15.4	14.9	15.2

Table 20 summarizes the data for Group C. The subordination index is 45.3 for the first sample, 46.5 for the second, and 45.9 for the combined writing. These indexes are slightly higher than the mid-scores on the two samples, 41 and 44 (see Table 19). The mean for the whole is, however, approximately 10 points higher than that for the high-school group (B), and suggests again the relation between complexity of thought and complexity of structure.

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[6] Garrett (11, p. 190): $\sigma = 1 - \frac{6 \Sigma D^2}{N(N^2 - 1)}$

The subordination index for this group is considerably higher than that for Boyd's (3) 18 novelists, previously referred to. He used a random sample of 100 sentences each. The samples, however, were conversation and hence not the natural expression of the writers themselves, but rather were their conception of how characters of varying ages and mentality would talk. Women novelists in writing conversation used an average of 37.5 and men one of 37 subordinate clauses to every 100 principal clauses. This would give subordination indexes of 27.2 (women) and 27.0 (men), much lower than for high-school pupils in the present study.

Of interest is the average length of clauses. While the average clause written by children in Group A contains 7.2 words, and that by high-school pupils (Group B) only 8.0, the formal writing of the psychologists here studied averages 15.2, or nearly twice as many words to a clause. This increase in length is apparently occasioned by the reduction of clauses to participial and infinitive phrases, and by the elision of words, phrases, and clauses. Analysis of such writing offers an interesting problem for further study, but does not fall within the province of the present investigation.

SUMMARY

Complexity of sentence structure as indicated by the ratio of subordinate to main predicates increases at least until age 16, and is accompanied by a tendency to increase the proportion of complex-complex sentences. Growth in this particular language skill appears to be dependent upon chronological age as well as upon mental age.

Analysis of the writing of superior adults suggests that, at least for certain individuals, marked growth in language skill, as measured by kinds of clauses used and by length and complexity of the clauses themselves, proceeds far beyond the level attained by high-school students. Such skill, even from a mere structural standpoint, is not attained by the most superior of the high-school students whose writing appears in this study.

VI

SEX DIFFERENCES

Certain comparisons to determine the possibility of sex differences are here presented. McCarthy, after summarizing the literature regarding sex differences in language development, concludes (19, p. 147):

> "Thus, from the numerous indications in literature, as well as from the consistent findings of the present investigation, it appears that girls develop more rapidly in the use of language than do boys at these early ages. Whether or not the difference is maintained at higher ages, we have not sufficient evidence to say, but as indicated above, there seems to be a tendency for the boys to equal the girls in language after the age of five or six years."

So far as the writer has been able to discover, no comparisons of language development according to sex have been made for individuals of school age or above, except those using either the quantitative approach or basing conclusions on information from achievement tests.

GROUP A

As far as general intelligence (as measured by the mental tests used) is concerned, the boys and girls in Group A are little different. Comparison is given (Table 21) of the intelligence quotients of boys and girls in this group. There are 222 boys and 260 girls. Mean intelligence quotient for the boys is 103.1, with a standard deviation of 15.75; for the girls, 105.85, standard deviation, 16.85. Median quotient for boys is 103.54; for girls, 104.12. Both mean and median for the girls are higher than for the boys, and girls

TABLE 21

DISTRIBUTION OF INTELLIGENCE QUOTIENTS FOR GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

IQ	Frequencies Boys	 Girls
60- 64.9		1
65- 69.9	2	2
70- 74.9	2	2
75- 79.9	9	3
80- 84.9	13	17
85- 89.9	25	20
90- 94.9	19	25
95- 99.9	24	32
100-104.9	24	34
105-109.9	40	28
110-114.9	17	28
115-119.9	21	20
120-124.9	11	12
125-129.9	5	9
130-134.9	1	9
135-139.9	3	6
140-144.9	2	10
145-149.9	2	1
150-154.9	2	1
Totals	222	260
Median IQ	103.54	104.12
Mean IQ	103.10	105.85
Standard deviations	±15.75	±16.85

are also slightly more variable as indicated by the standard deviation. Differences are, however, so slight as to be negligible.

Table 22 summarizes by sexes certain of the data presented in previous chapters. The 222 boys write a total of 27,687 words, or an average of 124.7 words per theme; the 260 girls, 38,569 words, or an average of 148.3 words per theme. The subordination index for all boys is 25.8; for all girls, 28.5. Boys write clauses containing 7.1 words; girls, 7.3. Girls excel

TABLE 22

COMPARISON BY SEXES OF NUMBER OF CASES, TOTAL NUMBER OF WORDS, AVERAGE NUMBER OF WORDS PER THEME, NUMBER OF PREDICATES, AVERAGE NUMBER OF WORDS PER CLAUSE, AND SUBORDINATION INDEX, FOR GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

	Boys	Girls	Total
Number of cases	222	260	482
Total number of words written	27,687	38,569	66,256
Average number words per theme	124.7	148.3	137.5
Number of predicates			
In independent clauses	2,910	3,739	6,649
In dependent clauses	1,014	1,493	2,507
In all clauses	3,924	5,232	9,156
Average number words per clause	7.1	7.3	7.2
Subordination index for group	25.8	28.5	27.2

in number of words written, in length of clauses, in number of predicates, and in tendency to use subordinate clauses. The differences are very slight, however, except in number of words. Two explanations which do not involve native ability, either general or special, may be offered. Girls may have been trained to conform more readily to school requirements than have boys, and may therefore write the longer papers which are generally approved by teachers, in a desire to please; or girls may find handwriting less difficult than do boys, and hence produce more composition within a given period. It should be noted in this connection, however, that not a single paper written by the pupils in Group A appeared unfinished. Practically all ended with some general statement denouncing a twelve-months plan. Apparently, therefore, boys were not interrupted in their writing. If the tendency to write a smaller quantity is learned behavior, it has become habitual. There is no evidence within the papers to indicate that boys fail to find the subject of their compositions interesting. On the contrary, they write with enthusiasm and considerable feeling.

The 3-per-cent difference between the subordination indexes of boys and girls appeared sufficient to require further analysis. Table 23 presents the subordination indexes by sexes for the various mental-age levels. No consistent differences appear. Boys excel at one level; girls at another. No evidence appears of the tendency observed by Jesperson (see Chapter I) that parataxis is a feminine characteristic.

TABLE 23

GROUP INDEXES OF SUBORDINATION BY MENTAL AGES AND BY SEXES FOR 222 BOYS AND 260 GIRLS IN GROUP A, 482 PUPILS, GRADES 4 TO 9, INCLUSIVE, FROM THREE KANSAS SCHOOLS

MA (months)	Frequencies		Number predicates		Number dep. preds.		Subordination index		
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	All
101-110	5	11	102	145	20	20	19.6	13.8	16.2
111-120	10	11	236	200	25	29	10.6	14.5	12.4
121-130	18	19	392	392	91	90	23.2	22.9	23.1
131-140	21	21	473	461	97	94	20.5	20.4	20.1
141-150	21	24	350	479	75	134	21.4	27.9	25.2
151-160	43	37	633	758	154	239	24.3	31.5	28.3
161-170	28	44	437	884	148	290	33.8	32.8	33.2
171-180	26	38	437	788	134	245	30.6	31.4	31.1
181-190	26	23	451	403	142	120	31.5	29.7	30.7
191-200	14	19	206	481	57	156	27.6	32.4	31.0
201-210	5	9	100	173	39	55	39.0	31.7	34.4
211-220	3	3	45	44	15	16	33.3	36.3	34.8
221-230	2	1	62	24	17	5	27.4	20.8	25.6
Totals	222	260	3,924	5,232	1,014	1,493			
Group indexes							25.8	28.5	27.4

GROUP B

Certain comparisons may be made from data for Group B. Distribution of intelligence quotients ap-

TABLE 24

DISTRIBUTION BY SEXES OF INTELLIGENCE QUOTIENTS FOR GROUP B, 504 PUPILS FROM LEAVENWORTH AND LAWRENCE (OREAD TRAINING), KANSAS, HIGH SCHOOLS

IQ	Boys	Girls	All
65- 69.9		1	1
70- 74.9	1		1
75- 79.9	4	4	8
80- 84.9	3	10	13
85- 89.9	17	20	37
90- 94.9	30	34	64
95- 99.9	44	40	84
100-104.9	45	54	99
105-109.9	40	41	81
110-114.9	32	23	55
115-119.9	14	16	30
120-124.9	10	9	19
125-129.9	7		7
130-134.9	2	2	4
135-139.9	1		1
Totals	250	254	504
Median IQ	102.88	101.66	102.22
Mean IQ	103.44	101.48	102.55
Standard deviations	±11.15	±10.63	±10.82

pears in Table 24. Median and mean intelligence quotients for boys are 102.88 and 103.44, respectively, with a standard deviation from the mean of 11.15; for the girls, 101.66 (median) and 101.48 (mean), with a standard deviation from the mean of 10.63. Boys in Group B excel slightly in intelligence, and are slightly more variable, but the difference is negligible, as with Group A.

Since detailed analysis was not made of the themes written by Group B, complete comparisons are not offered. The one sex difference noted for Group A is, however, studied also for Group B. Table 25 presents the data. The 254 girls write a total of 45,498 words, or an average of 179.1 per pupil in the given time; 250 boys write only 37,164 words, or an average

TABLE 25

COMPARISON BY SEXES OF TOTAL NUMBER OF WORDS AND AVERAGE NUMBER OF WORDS PER THEME, FOR GROUP B, 504 PUPILS IN LEAVENWORTH AND LAWRENCE (OREAD TRAINING), KANSAS, HIGH SCHOOLS

	Boys	Girls	Total
Number of cases	250	254	504
Total words written	37,164	45,498	82,662
Average words per theme	148.6	179.1	165.9

of 148.6 per pupil. As previously stated, boys in Group A write approximately 86 per cent as many words in a given time as do the girls. In Group B, they write 83 per cent as many. The tendency is significant in view of the fact that many teachers of English make quantity assignments in composition courses. One cause for the relatively high performance of girls in language courses may possibly be found in the foregoing.

SUMMARY

No sex differences are apparent from a comparison of the intelligence quotients of boys and of girls in Groups A and B.

The only sex difference revealed by a comparison of the papers of the boys and girls in Groups A and B is the tendency of the girls to write more words in a given length of time. Boys in Group A wrote themes only 86 per cent as long as those written by girls; in Group B, boys' themes were 83 per cent as long as the girls'.

In length of clause and proportion of subordinate to main clauses, the compositions of the boys and of the girls in Group A do not differ. Comparisons were not made for Group B.

VII

SUMMARY AND CONCLUSIONS

The present study investigates language development, using the clause as the unit for study. The uses made of clauses are considered significant indications of skill in language use.

The clause rather than the sentence is used because it is impossible to determine what constitutes a sentence in an individual's oral or written composition, unless the sentence be perfectly punctuated by marks or inflection. In spoken composition inflection frequently is not a guide.

The composition studied is the written expression of 1007 individuals, comprising three groups:

Group A, 482 pupils in Grades 4 to 9, inclusive.
Group B, 504 pupils in Grades 9 to 12, inclusive.
Group C, 21 eminent psychologists.

The writing of these individuals totals 161,518 words and includes 20,320 predicates or clauses.

All clauses are classified according to two major categories: main and dependent clauses. For each of the 1007 individuals a subordination index is computed by dividing the number of subordinate clauses by the total number of clauses he wrote. This subordination index is therefore the percentage which dependent clauses constitute of the total clauses written by each individual.

Clauses written by Group A, children in Grades 4 to 9, inclusive, are further classified according to the following outline.

- I. Independent clauses
- II. Dependent clauses, used as
    - *A.* Adverbs, to express time, cause, condition, concession, place, purpose or result, comparison
    - *B.* Nouns
    - *C.* Adjectives

A detailed study of the clauses written by Group A yields the following results:

1. Correlation by the Pearson product-moment formula between mental age and subordination index scores for the 482 individuals gives a coefficient of only 0.29±.03; between chronological age and subordination index, 0.41±.03.

2. When median or mean scores are taken for mental-age groups of ten months each, however, increase of index is found to accompany increase of mental age except in extreme groups where chronological age varies greatly from mental age. High chronological age in these groups accompanies an increase in subordination index, and low chronological age a corresponding decrease.

3. Within mental-age units of ten months, subordination index follows chronological age when mean scores are considered.

4. It appears, therefore, that the tendency to use increasing proportion of subordinate clauses is a mark of increasing language development from Grades 4 to

9, inclusive (mental age, 101-230 months; chronological age, 101-192 months), and that this tendency is a function both of mental and of chronological age.

Detailed study of the functions of subordinate clauses used by Group A discloses the following:

1. While with the increasing age of the writers the number of each type of dependent clauses increases in proportion to the total number of clauses used, the distribution of these dependent clauses into the various functional categories (clauses of time, place, and so forth) remains fairly constant.
2. The percentages of condition, concession, place (adverbial), purpose and result, and comparison clauses are so small at every mental-age level as to form an insignificant share (approximately 6 per cent) of the total clauses used. This fact is important in the development of functional-grammar curricula.
3. The content of subordinate clauses becomes more exact with increasing maturation of the writers. Time clauses, for example, change from *when*-clauses to *after-*, *until-*, *while*-clauses, and so forth.
4. The most of the noun clauses are used as direct object of the verb, over 60 per cent as object of a verb of thinking, saying, or believing. Noun clauses as subject or in the predicate appear only once in every 26 examples.
5. Adjective clauses and clauses of comparison are the only subordinate clauses which offer structural difficulties.
6. Length of clauses remains comparatively con-

stant between ages 8 and 16, the mean length for mental-age groups in this study varying from 6.6 to 8.7 words.

Analysis of clauses used by Group B, 504 high-school students, suggests the following:

1. Approximately 36 per cent of the clauses used by high-school students 16 years of age or older are subordinate. Conversely, the percentage of dependent clauses used in writing increases until age 16 or above.
2. High intelligence quotient does not appear to exert a marked influence in hastening the use of complex sentence structure. Chronological age does appear to exert an influence when mental age is constant.
3. Length of clause (average length, 8.0 words) for this older group is only slightly greater than that (7.2 words) for the younger pupils of Group A.
4. Increased dependence on dependence accompanies increased percentage of hypotaxis.

The writing of Group C, 21 eminent psychologists, shows marked variations from the writing of Groups A and B.

1. The median subordination index for this group is 45.3 for the first sample, 46.5 for the second. This is approximately 10 points higher than that for the high-school pupils of Group B.
2. The average length of clause for this group is 15.2 words, or nearly twice as many as are found in the clauses of Groups A and B. This increase in length is accompanied by increase in complexity of structure.

3. The language skill disclosed by these superior adults is not attained, even from a structural standpoint, by the most superior of the high-school students whose writing is used in this study.

Sex differences are insignificant save in one particular: girls in Group A write an average of 148.3 words per theme, while boys writing on the same topic and for the same length of time write an average of only 124.7 words. Boys' papers give evidence of as much interest in the subject as do girls'. Girls in Group B likewise write an average of 179.1 words, while boys write only 148.6.

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UNE ÉTUDE DE CERTAINS DÉVELOPPEMENTS DU LANGAGE CHEZ LES ÉLÈVES DES ANNÉES SCOLAIRES QUATRE À DOUZE INCLUSIVES

(Résumé)

Cette étude s'occupe du développement du langage avec la proposition comme unité. Les compositions étudiées ont été écrites par 1007 individus; Groupe A, 482 élèves des années scolaires quatre à neuf, inclusives; Groupe B, 504 élèves des années scolaires neuf à douze, inclusives; Groupe C, 21 psychologues éminents. L'écriture fait un total de 161.518 mots et de 20.320 propositions. On a classifié les propositions selon deux catégories principales, principales et dépendantes. On a computé un indice de subordination pour chaque individu en divisant le nombre de propositions subordonnées par le nombre total des propositions écrites. On a classifié d'ailleurs les propositions écrites par le Groupe A, selon l'usage: adverbiales (temps, cause, condition, etc.); substantives; adjectives.

L'étude des propositions écrites par le Groupe A donne les résultats suivants:

1. La corrélation selon la formule Produit-Moment de Pearson entre l'âge mental et les résultats de l'indice de subordination pour les *individus* donne un coefficient de 0,29±0,03 seulement; entre l'âge chronologique et l'indice de subordination, de 0,41±0,03.
2. Les résultats médians ou moyens pour les *groupes* d'âge mental, chacun de dix mois, montrent cependant un accroissement de l'indice lequel accompagne un accroissement de l'âge mental sauf dans des groupes extrêmes où l'âge chronologique varie beaucoup de l'âge mental.
3. Dans les unités d'âge mental de dix mois, l'indice de subordination suit l'âge chronologique quand l'on considère les résultats moyens.

L'étude des *fonctions* des propositions subordonnées employées par le Groupe A montre les résultats suivants:

1. La distribution des propositions dépendantes dans les diverses catégories de fonctions (temps, endroit, etc.) reste assez constante avec l'accroissement de l'âge des sujets.
2. Le contenu des propositions subordonnées devient plus exact avec la maturation augmentante des sujets. Les propositions de temps, par exemple, changent de *quand*-propositions à propositions avec *après que, jusqu'à ce que, pendant que,* etc.
3. Seulement les propositions adjectives et celles de comparaison offrent des difficultés de structure.
4. La longueur des propositions reste comparativement constante entre les âge de huit et de seize.

L'analyse des propositions employées par le Groupe B montre les résultats suivants:

1. Approximativement 36 pour cent des propositions employées par les élèves de l'école secondaire âgés de seize ans ou de plus sont subordonnées.

Le pourcentage des propositions dépendantes s'accroît jusqu'à l'âge de seize ans ou de plus.

2. Un quotient élevé d'intelligence ne semble pas être une influence qui fait venir plus rapidement l'emploi de phrases complexes. L'âge chronologique ne semble pas être une influence quand l'âge mental est constant.

3. La longueur moyenne des propositions pour le Groupe B est plus grande seulement de 0,8 mots que pour le Groupe A.

4. Une plus grande dépendance sur l'indépendance accompagne une plus grande hypotaxe.

L'écriture du Groupe C montre des variations marquées de l'écriture des Groupes A et B.

1. L'indice médian pour ce groupe est de 45,3 pour le premier échantillon, de 46,5 pour le second, approximativement plus élevé de 10 points que pour le Groupe B.

2. La longueur moyenne des propositions est 15,2 mots, presque deux fois la longueur pour les Groupes A et B. Une plus grande longueur est accompagnée d'une plus grande complexité de structure.

Les différences de sexe sont insignifiantes à l'exception du fait que les jeunes filles des Groupes A et B écrivent plus de mots que les garçons dans un temps donné.

LABRANT

EINE UNTERSUCHUNG GEWISSER SPRACHENTWICKLUNGEN BEI KINDERN DER VIERTEN BIS EINSCHLIESSLICH DER ZWÖLFTEN SCHULKLASSE

(Referat)

In dieser Arbeit wurde die Sprachentwicklung untersucht, wobei der Satzteil als Einheit diente. Die untersuchten Schriften (Aufsätze) stammen von 1007 verschiedenen Versuchspersonen. Die Gruppe A bestand aus 482 Schülen der vierten bis einschliesslich der neunten Schulklasse; die Gruppe B, aus 504 Schülern der neunten bis einschliesslich der zwölften Schulklasse; und die Gruppe C, aus 21 hervorragenden Psychologen. Die Schriften betrugen im ganzen 161,518 Wörter, 20,320 Satzeinheiten. Die Satzeinheiten werden nach zwei grossen Hauptkategorien klassiert—Hauptsatzeinheiten und abhängige Satzeinheiten [dependent clauses]. Für jede Versuchsperson wurde ein Unterordnungsindex [subordination index] dadurch ermittelt, dass man die Zahl der untergeordneten (abhängigen) Satzeinheiten durch die Gesmatzahl der von dieser Versuchsperson geschriebenen Satzeinheiten dividierte. Die von der Gruppe A geschriebenen Satzeinheiten wurden weiterhin auf Basis der Anwendung der Satzeinheit klassiert [classified as to use]: adverbial (als Ausdruck der Zeit, der Ursache, der Umständen, u.s.w.); hauptwortlich, d.h., Anwendung der Satzenheit als ob sie ein Hauptwort wär; und eigenschaftswortlich.

Eine Untersuchung der von der Gruppe A geschriebenen Satzeinheiten lieferte folgende Resultate:

1. Die mit der Pearson'schen Produkt-Moment Formel ermittelte Korrelation zwischen dem geistigen Alter [mental age] und den Abhängigkeitsindexzahlen [subordination index scores] der *Individuen* beträgt nur 0.29 ±.03; zwischen dem kronologischen [tatsächlichen] Alter und dem Abhängigkeitsindex beträgt die Korrelation 0.41±.03.

2. Berücksichtigt man aber die mittleren oder die Durchschnitt-Zahlen *gruppenweise (in Gruppen von je zehn Monaten), so liefern sie Korrela*tionzahlen welche mit der Zunahme des geistigen Alters einhergehende Zunahmen erweisen, ausser in den extremen Gruppen worin sich das kronologische Alter stark von dem geistigen Alter unterscheidet.

3. Innerhalb geistiger Alterseinheiten [mental-age units] von 10 Monaten folgt der Abhängigkeitsindex dem kronologischen Alter, wenn man die durchschnittlichen Zahlen berücksichtigt.

Untersuchung der Funktionen der von der Gruppe A benutzten Satzeinheiten liefert folgende Resultate:

1. Die Verteilung der abhängigen Satzeinheiten auf die verschiedenen funktionellen Kategorien (Zeit, Ort, u.s.w.) bleibt bei zunehmendem Alter der Versuchspersonen ziemlich konstant.

2. *Der Inhalt der abhängigen Satzeinheiten wird mit zunehmender* Reife der Versuchspersonen genauer. Die sich auf Zeit beziehenden Satzeinheiten [time clauses] verändern sich von *Wann*sklauseln [*when* clauses] in *Nach*klauseln [*after* clauses], *Bis*klauseln [*until* clauses], *Während*klauseln [*while* clauses], u.s.w.

3. Nur Eigenschaftswort- und Vergleichungsklauseln machen den Versuchpersonen strukturelle Schwierigkeiten.

4. Zwischen 8 und 16 Jahren bleibt die Länge der Satzeinheiten relativ konstant.

Analyse der von der Gruppe B benutzten Satzeinheiten lieferte folgende Resultate:

1. Ungefähr 36 Prozent der von Schülern der höheren Schulen, 16 Jahre *alt oder älter, benutzten Satzeinheiten waren abhängige.* Der Prozentsatz der abhängigen Satzeinheiten nimmt bis zu 16 Jahren, oder länger, zu.

2. Ein hohes Intelligenzquotient scheint die Benutzung von komplizierten Satzstrukturen nicht zu beschleunigen. Durch das kronologische Alter, anderseits, scheint diese Benutzung, bei konstant erhaltenem geistigen Alter, beeinflusst zu werden.

3. *Durchschnittlich benutzt die Gruppe B nur 0.8 Wörter mehr per* Satzeinheit als die Gruppe A.

4. Die Zahl der von schon-abhängigen abhängigen Satzeinheiten nimmt mit Zunahme der Hypotaxe zu.

Die Schriftstellerei [writing] der Gruppe C weicht stark von der Schriftstellerei der Gruppen A und B ab.

1. Der mittlere Index dieser Gruppe (C) beträgt für das erste Exemplar 45.3, für das zweite, 46.5; ist also um ungefähr 10 Punkt höher also bei der Gruppe B.

2. Die Satzeinheiten enthalten durchschnittlich 15.2 Wörter—also fast zwei Mal so viele wie die der Gruppen A und B. Die Zunahme an Länge geht mit einer Zunahme an Kompliziertheit der Satzstruktur einher.

3. *Die Geschlechtsunterschiede sind ohne Bedeutung, mit Ausnahme* der Tatsache, dass sowohl in der Gruppe A wie in der Gruppe B die Mädchen innerhalb eines gegebenen Zeitraumes mehr Wörter schreiben, als die Knaben.

LaBrant

Journal of General Psychology

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Child Behavior, Animal Behavior, and Comparative Psychology

THE EFFECT OF EARLY AND DELAYED PRACTICE ON MEMORY AND MOTOR PERFORMANCES STUDIED BY THE METHOD OF CO-TWIN CONTROL*[1]

From the Clinic of Child Development, Yale University

By

JOSEPHINE ROHRS HILGARD

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I

STATUS OF THE PROBLEM

The effect of practice on the developing abilities of young children is an integral part of the larger problem of native and acquired behavior, a problem which has been important systematically and educationally in such concepts as instinct and intelligence. Emphasis on the dichotomy between the rôles of heredity and environment, which characterized early experimentation, has gradually changed to an emphasis on the conditions of variation which may alter development. For an introduction into the problems of this vast field, the reader is referred to recent articles by Gesell (13), Shirley (29), and Witty and Lehman (36).

Table 1 presents a résumé of some of the studies definitely bearing on the relative effects of controlled practice on the performances of children. Information regarding the subjects, their ages, the performances tested, and the length of the practice period has been summarized there. The general findings of these studies will be briefly reviewed.

Gates and Taylor (9) found that immediate practice in memory for digits resulted in a marked gain in ability of a practice group over the control group. After 4.5 months of no practice, however, the two groups were again equal; the practice group had entirely lost its advantage. After 3.5 more months without practice, when both groups were given 22 days of intensive training, the two groups were still approxi-

TABLE 1

PREVIOUS INVESTIGATIONS: EFFECT OF PRACTICE ON DEVELOPING PERFORMANCES IN CHILDREN

P=*Practice group*
C=control group
B=both groups

Investigator	Date	Performances	Subjects P	Subjects C	Age at beginning	Procedure
1. Gates and Taylor (9)	1925	Digit-memory	16	16	4-6 years	P: 78 days' practice over 4.5 months. C: tested on 1st and last of 78 days. B: retests 4.5 months later; 22 days' practice 8 months after end of practice.
2. Gates and Taylor (10)	1926	Tapping	28	28	4-6 years	*B*: 18 days' *initial practice*. *P*: 76 days' practice over 6 months. C: 10 days' practice at end; retests 6 months later.
3. *Goodenough* and Brian (16)	1929	Ring-tossing	4 6 10 (3 groups)		4 years	All groups: 50 days' practice. Group A—no instruction, B some instruction, C thorough instruction.
4. Gesell and Thompson (14)	1929	Climbing Cube behavior	1	1	46 weeks	P: 6 weeks' daily training. C: 2 weeks' daily training at end of first training period.
5. Strayer (30)	1930	*Language*	1	1	84 weeks	P: 5 weeks' daily training. C: 4 weeks' daily training at end of first training period. Retest 3 months later.
6. Hicks (19)	1930	Throwing ball at moving target	30	30	2½-6½ years	*P*: 8 weeks' *practice once a week*. *B*: 2 final days of tests.
7. Hicks (18)	1930	Tests only: strength, perforation, tracing	30 (same as in 6)	30	2½-6½ years	B: tested at beginning of target experiment and again 3 months later.
8. Hicks and Ralph (21)	1931	*Porteus diamond maze*	12	12	24-40 months	P: 7 weeks once a week. B: initial and end tests with right and left hands.
9. Jersild and Bienstock (24)	1931	*Musical pitch* and interval	18	18	31-48 months	P: 6 months twice a week to total of 40 practice periods. C: compared at beginning and end. *B*: average of 3 days on initial tests.
10. Jersild (23)	1932	Speed of color naming	17	17	6-7 years	P: 3-4 months of training 3 times a week; *except 6 months 2 or 3 times a week in pitch* and tonal intervals. B: retests 3 months after training in color naming, free association, and strength of back. retests 4 months after training in free association, strength of grip, vital capacity, tapping, pitch, and tonal intervals. retests 8 months after training in *strength of* grip.
		free association	16	16	9-10 years	
		strength of grip	19	19	4-6 years	
		strength of back	15	16	2-3 years	
		vital capacity	22	22	5-7 years	
		tapping	7	7	2-3 years	
		musical pitch	18	18	2-3 years	
		tonal intervals	16	16	2-3 years	
11. Hilgard (22)	1932	Cutting, buttoning, climbing	8-10	8-10	2-3 years	*P*: 12 weeks' *practice twice a week*. C: 1 week with 4 days' practice at end of 12 weeks.
12. Burtt (2)	1932	Original Greek	1		15 months	P: 15-36 months' daily listening to Greek; retest at 8½ years.
13. Mattson (28)	1933	3 mazes graded in *difficulty*	25	25	4 years 10 months to 6 years	B: 4-day practice. P: 26 days' additional practice. B: 8 days of tests, then 2 months of *non-practice* and again 8 days of tests.

mately equal. Thus no permanent effects of the 78 days of practice could be found. Gates and Taylor interpreted these facts to mean that improvement from specific practice was due to the acquisition of special and subtle techniques or adjustments which were unstable and transitory. Their tapping experiment (10) showed that after an initial rapid gain improvement during the practice period was slow and steady. Though the control group was inferior to the practice group at the end of the practice period, 10 days of practice resulted in making the two groups equal. Six months later both groups were found to be substantially equal. On the basis of these facts, improvement was attributed to the steady growth of the neural and other mechanisms concerned, plus the acquisition of working methods.

Gesell and Thompson (14) emphasized the importance of the method of co-twin control for studying the *effect of practice on developing behavior patterns.* Their results pointed consistently to the importance of maturational factors in the determination of infant behavior pattern. The climbing performance of Twin *C* at 55 weeks was far superior to the climbing performance of Twin *T* at 52 weeks even though Twin *T* had been trained seven weeks earlier and three times longer. In cube behavior, at the end of the training period for Twin *T* it was impossible to demonstrate any significant influence of the training. Strayer (30), using co-twin control on Twins *T* and *C* in early and deferred language practice, showed that the deferred practice was more effective. Follow-up contact after a period of three months, however, indicated that the differences were disappearing if not entirely gone.

Goodenough and Brian (16) tested the development of skill in throwing rings over a post. Three groups of preschool children were used. Group A, which had received no instruction during practice, progressed 11.5 score points in comparison with 17.5 for Group B, which had received some instruction, and 42.5 for Group C, which had received thorough instruction. This study indicates the necessity for controlling factors concerned with the type of practice or training.

In the development of motor coordination in children as measured by the moving-target test, Hicks (19) found that both practice and control groups made gains in average score from the initial to the final tests, but that difference in gains was not significant. In a parallel study (20) the same children were given strength, perforation, and tracing-path tests once during the period when the initial target tests were given, and again when the final target tests were given, approximately three months later. On the strength and perforation tests the increases in skill without specific practice as shown by the tests were comparable to increases on the target test either with or without specific practice, while on the tracing test slight losses were found. The results of both studies were interpreted to mean that improvement in skill probably resulted from the operation of factors such as structural maturation and general practice. Hicks and Ralph (21) found in their maze test that practice did not result in significantly greater skill. The large increase in skill in both groups could again be attributed mainly to structural maturation and general practice.

The experiment by Jersild and Bienstock (24) indicated that children's performances in reproducing pitch and interval could be much improved through training. They suggest that musical training at the age of three could be undertaken with promising results. Jersild (23), in a further study on the ability to sing tones and intervals, found that not only did the practiced children make a decided gain over the controls but they retained this favorable position on retests four months later. Jersild observes that the gains were made by learning new tones and intervals. This experiment on music was part of a larger investigation. In the experiments on color naming, free association, strength of grip, strength of back, and tapping, the practiced children showed some advantage over the controls at the end of training. This ranged from a small advantage in tapping, vital capacity, strength of back, and free association which was entirely gone three months later, to a greater advantage in color naming and strength of grip. At the end of three months the practice group no longer maintained significant advantage in color naming but did retain its advantage in strength of grip. This difference dropped out on retesting seven and a half months after training had ceased. Jersild states that practice apparently did not bring about changes beyond the limits determined by the child's degree of maturity.

Hilgard (22), training in the skills of buttoning, cutting, and climbing, found that after twelve weeks of practice the practice group exceeded the performance of the control group on all the tests, but one week of practice by the control group was sufficient to bring the scores of the control and practice groups to similar levels. The rapid relative gains of the control group were interpreted to mean that factors other than specific training contributed to the development of these three skills, factors which may be accounted for partly by maturation and partly by incidental practice in related skills. Evidence from the learning curves of the practice group in buttoning and climbing showed that improvement was more rapid in the latter part of the training period, consistent with the accelerated learning of the control group at the end of the experiment.

In a very suggestive experiment, Burtt (2) found that original Greek selections which were read daily to a child between 15 months and 3 years of age were recalled at the age of 8½ years in fewer repetitions than similar new material in Greek. The new material required 435 repetitions per selection; the material presented in infancy and early childhood required 317. These data must be given serious consideration because of their educational implications. Measurement at various ages after an experiment would appear important.

Mattson (28) investigated the relation between level of complexity in skill and effectiveness of practice on retention. She found that, if the situation was simple, a few trials to adjust the individual to a particular situation plus an interval of time were necessary to achieve skill; if the situation was complex, considerable specific practice plus a given maturational level was necessary. Loss or gain after a period of non-practice was related to the level of performance at the interruption of learning. Rest periods during early stages, when improvement was more rapid, resulted in slight changes either of gain or loss. Rest periods later, when the curve was flattening, resulted in relatively greater loss in skill. Forgetting did not proceed more rapidly on complex than on simple levels over a 60-day period.

The accumulation of data in the above studies is contributing to a more adequate sampling of the effect of practice on a variety of performances. Interrelationships gradually become clearer. For example, a single performance has been studied at different age levels; we now have data on tapping from Jersild (23) on children aged 2-3 years and from Gates and Taylor (10) on children aged 4-6 years. Within a given age range, more performances are being subjected to experimentation; on the age range from 2-3 years we have had experiments by different investigators on maze behavior, strength of back, tapping, musical pitch and interval, cutting, buttoning, and climbing. Some of the differences in findings are attributable to differences in specific methods used. It becomes increasingly possible to account for these differences as the field is explored more thoroughly. The present experiment is an attempt to further the analysis of the problem.

II

GENERAL PLAN OF THE EXPERIMENT

In order to test further the influence of controlled practice on the development of behavior, a pair of identical twins was chosen for study. It seemed of interest to continue the use of the method of co-twin control at a more advanced developmental level. Longer exposure to general environmental conditions might have produced differences between the twins which would invalidate the method for use with older children.

Twins *T* and *C*, aged 4½ years, were available for study at the Clinic of Child Development. This is the pair of identical twins used by Gesell and Thompson (14) when they were between the ages of 46 and 54 weeks in the study of climbing and cube behavior; by Strayer (30) between the ages of 84 and 93 weeks in her study of language development; by Partridge[2] between the ages of 27 and 36 months in an investigation of drawing and language; and by Gesell, Thompson, and Lytle (33) between the ages of 43 and 49 months in a study of the control of attention. The twins have been observed periodically at the Clinic of Child Development from the age of 6 weeks. The present experiment extended over the period of a year, from January, 1932, to January, 1933, when the twins were 54-66 months of age.

From the many performances which might have been selected for investigation, certain ones appeared to have a more strategic relationship to other investigations. In order to compare the co-twin control method with a study using a large number of children, the digit-memory test was chosen. This had been used by Gates and Taylor (9) on children of similar age. An object-memory test was added for the purpose of sampling another mnemonic function. That each child might serve as both practice and control subject throughout the experiment, a set of performances quite removed from memory were chosen. The test of cutting made possible a comparison with the group study previously reported by the author (22). Walking-boards of various sizes (1, 25) provided a motor test graded in difficulty. The ring-toss, as suggested by

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[2] Unpublished study.

GENERAL SCHEME OF EXPERIMENT

Consecutive periods Jan., 1932 to Jan., 1933 Twins aged 54-66 months	Procedure	
	Twin *T*	Twin *C*
1. 4 weeks (initial test)	Tested twice: all items.	Tested twice: all items.
2. 8 weeks	Practice: walking-boards and ring-toss.	Practice: digit- and object-memory, cutting.
3. 4 weeks (first retest)	Tested twice: all items.	Tested twice: all items.
4. 8 weeks	Practice: digit- and object-memory, cutting.	Practice: walking-boards and ring-toss.
5. 4 weeks (second retest)	Tested twice: all items.	Tested twice: all items.
6. 12 weeks (third retest)	No practice. Tested twice on all items at end.	No practice. Tested twice on all items at end.
7. 12 weeks(fourth retest)	No practice. Tested twice on all items at end.	No practice. Tested twice on all items at end.

Motor items: cutting, ring-toss, walking-board.
Memory items: Object-memory, digit-memory.
Practice occurred three times a week during the practice periods.

Goodenough and Brian (16), furnished performances differing in the perceptuomotor coordinations involved. Under the proposed experimental set-up of reversed practice and control, both twins could be trained at once so that cooperation and confidence in the experimenter, attention to the experimental situation, and similar factors might be controlled.

The experiment departed from the general plan of previous experiments by using each twin both as practices and as control in the memory and motor items throughout the experiment. The general scheme is indicated in the accompanying schedule.

Test periods were the same for both children, while practice periods 2 and 4 constituted reversals of practice and control. Periods 6 and 7 served to show the influence which previous special practice may have exerted as well as to check the similarity or dissimilarity of growth unhampered by immediate special practice in the same two children.

III

GENERAL CHARACTERISTICS OF THE SUBJECTS

That subjects *T* and *C* were highly similar twins has been established by previous work carried on at the Clinic of Child Development (12, 14, 30). At the beginning of this experiment, when the twins were 54 months of age, they were tested in a number of ways in an effort to find similarities and differences which might affect the experiment.

Physically, the children resembled each other to a marked degree. For example, during the initial developmental examination, *T*, a little restless, turned to the curtain at the head of the crib. Pulling it aside, she looked into a mirror exposed there and said, "*C* is in there. She is standing right over there." At this point the examiner replaced the curtain. Later, while undressing, *T* again turned back the curtain, saw her mirror image, and exclaimed, "There is *C*; she is undressing too." Then *T* looked in back of the mirror, in front of it, felt of it, and finally said, "Why, that isn't *C* at all. It's a mirror." Since *C* did not exhibit the same spontaneous curiosity regarding the curtain, the examiner suggested that she pull it back. *C* complied and smiled. To the examiner's question, "Who is it?" she replied, "*T*." The examiner then asked, "Where is she?" and *C* answered, "In there." When pressed further, *C* decided that it was not her twin but herself. All physical measurements at this time showed marked similarities.

On the mental examination the twins received similar ratings: Stanford-Binet (32) MA for *T* was 48 months; for *C*, 50 months. The general rating on the C. C. D. developmental schedule (11) was practically the same. On the Goodenough drawing test (15) *T* scored an MA of 60 months; *C*, one of 54 months. In regard to vocabulary, *T* and *C* received the same score of 48 months on the Van Alstyne test (34), while on the Merrill-Palmer action agent test (31) *T*'s rating was placed between 36-41 months, while *C*'s was 36 months. The differences in MA seem not to be significant. When the individual responses were compared, *T*'s were superior in some ways to *C*'s, while in others *C*'s were superior to *T*'s. During the examination it was noted that *C* was less talkative, evinced more interest in fine motor coordination, and was more restrained than her twin.[a]

Additional tests related to the activities of the main study were given: in handedness and manual speed, because of their importance in cutting and ring-toss; in footedness, because this constituted a possible factor in skill on the walking-boards; in memory, so that an adequate sampling of similarities and differences might be obtained before using certain memory functions for intensive study; and, finally, in perseveration, as an aid in personality diagnosis. In handedness, using tests described by Haefner (18) and Gates (8), very little difference appeared; *T* and *C* preferred the right hand in all performances with the exception that *T* clasped a broom with her left hand on top. Using Cuff's test for footedness (5), it was found that both children kicked four times as often with the right foot as with the left. On the manual speed tapping tests (17) *T* maintained a consistently slower tempo; an average of 22.1% fewer taps for the four situations of right bimanual, right unimanual, left bimanual, and left unimanual.

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[a] Jones and Wilson (26) comment that a slight divergence in strikingly similar twins is apt to stand in marked relief. This is the case in differences noted between Twins *T* and *C* for they were markedly alike even in these characteristics.

On memory tests of the Stanford-Binet, *T* and *C* had done equally well in digits, getting 4 digits correct in one of three trials; memory for sentences gave *C* a slight superiority at year 4 where she scored 1 to *T*'s ½ point. The Knox cube test of rote memory brought out a personality difference rather than a reliable score difference between the twins, for, although *T* gave a good performance, *C* did not direct her attention for any length of time toward the task, preferring to play with the blocks themselves. Using the technique developed by Foster (7) in testing memory for stories, it was possible to obtain simultaneous performances in a memory function. Trials were spaced at two- and three-day intervals. The results, interesting in reference to the memory experiment proper, show that in this function simultaneous practice resulted in similar performance. The data are presented in Table 2.

A modified battery of perseveration tests (6) was given to the twins at the beginning of the experimental period, at the end of intensive training periods in June, and again as a check in October. The perseverative

TABLE 2
T AND C: MEMORY FOR A STORY
"The Dog and the Kittens"

Trials	*T*	*C*
1	0	0
2	16	18
3	30	31
4	37	37
5	47	54
6	66	61
7	73	72
8	71	67

function, which is defined by Cushing as the ability to remain at a more or less routine task, such as dropping marbles into a can through a hole in the top, was consistently different in the two children on the January and June examinations. *T* remained at each of the eight situations longer than *C*, and her total time spent on the toys was twice as much.[4] This confirmed a general impression that *T*'s attention to a task was apt to be longer than her sister's. On the October examination, however, the children were practically equal in total time; *T* spent a little less time than on previous examinations, but *C* increased her time greatly and in certain situations spent longer than *T*. In view of the January data at the start of the experiment, it seemed important to plan practice periods which would be short enough to interest each child for the total period. Consequently, the number of trials on each test was limited to a number which seemed to produce maximum effort on the part of each child for the duration of the period.

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[4] The effect of practice on attentional factors which involved the training of Twin *T* from the age of 27 months to 36 months (33) may be evident in these tests.

The twins were markedly similar in the majority of initial tests in the main study. On digit-memory, object-memory, ring-toss, and walking-boards of 2 and 4 centimeters, scored in terms of errors, the similarity was pronounced. Slight differences were evident in the number of deviations made in cutting. A decided difference appeared in the error score for the walking-board of 6 centimeters.

IV

EXPERIMENTAL PROCEDURES, MATERIALS, AND SCORING DEVICES

A. General Procedures

Except for minor colds, neither twin was ill throughout the experimental period with the result that test and practices came exactly as scheduled, Tuesday, Thursday, and Saturday in the morning between the hours of 9:00 and 11:00. When both motor and memory items were presented to each child as tests, *T* and *C* were given them on successive days. Practice periods spaced at the same intervals for both children, three times a week for eight weeks, totaled twenty-four in each part of the experiment. Inasmuch as procedures, techniques, and number of trials were identical in the test and practice periods, it was possible to construct curves of learning or memorization from averages of the practice trials for each week. Here it should be noted that each average test score was based on the results of two test periods given during a four-week interval while each week's average practice score represents three day's work within the week.

To control the effect of fatigue and to show no preference to either twin, the children took turns going first with the examiner. While one twin received practice, the other played with toys unrelated to the experiment in the waiting-room under the supervision of a secretary.

Practices and tests always took place in the same room. Full instructions were given to a subject before starting each test. After the first test periods, however, it would have been strained to repeat all instructions verbatim as the children became entirely familiar with the procedure. Consequently, brief directions soon took the place of the first longer ones. The emphasis was to have every situation as natural as possible. No coaching was attempted because of the difficulty of measuring the amount at any given time or estimating its influence at a particular part of the learning process. Since Goodenough and Brian (16) have shown that the degree of instruction probably influences the development of a specific skill, it seemed better to keep such a variable factor controlled as much as possible. When a child had performed creditably, the experimenter would comment, "Good," "Good work," "That was well done," and, in general, share the child's pleasure of achievement. If, on the other hand, there were difficulties, the experimenter would say, "I think you can do better this time," "*Now* let's see how well you can do it," "Do your best." Whenever reminders seemed to be needed, parts of the original instructions were repeated.

It was easy to establish a friendly and playful relation with both children. Cooperation proved excellent from the start. Activities for each morning were treated as games to be taken as a matter of course. Order of tests depended both on the child and on the experimenter. It seemed more important to foster desire for active participation on the part of the child than to adhere to a rigid order of tests where one test always came first and the others in their exact places. The child was permitted to choose the test, but by means of suggestion the experimenter was able to modify choices so that there was approximately equal order for the different activities during the practice periods. In test periods, the order of presentation was identical for each child. After all experimental sessions, there was a short period before returning to the other twin when the child could choose a toy for play from a number of toys not in any way associated with the test materials. This procedure added variety to each morning's experience. Numerous little routine games, such as surprising the other twin, saying "boom" on steps, or treating benches like horses, not only added zest to the experimental life but greatly increased the comradeship of subjects and experimenter.

B. TESTING THE ABILITY ATTAINED IN MEMORY FOR DIGITS

Cards, each with nine series of digits, constituted the material for this test. Three of the series consisted of 3-digit combinations, three of 4-digit combinations, and *three of 5-digit combinations.* These *performances* are located on the Stanford-Binet test at years 3, 4, and 7, respectively. Procedure and directions were similar to those on the Stanford-Binet. First the child was presented orally with the 3 digits, then 4, and finally 5. If she succeeded on the first trial with three digits, the experimenter immediately gave the 4-digit series. Here all three trials were given regardless of failure or success. Finally, came the series of 5 digits; two trials on these generally sufficed because of attention and fatigue factors.

To eliminate verbatim learning of any particular series, six cards with varying combinations of digits were employed. General rules for the construction of test material were followed. By using six different cards of digits the same sequence of numbers occurred once every two weeks, or four times during the practice period. At test periods when both children were given the digit test, the same list of digits was presented to each of them.

If the child wished to sit at the small table she could do so; on the other hand, if she wished to stand near the wall, that was permitted. The only set requirement was that the child should be quiet with attention focused on the experimenter. Both children like the game of standing in a corner of the room, moving to a new corner with each success, and finally standing next to E for the last numbers. Then a twin sometimes would have E stand in the corners while she looked very seriously at the card to "read" the numbers for repetition. Occasionally interest flagged somewhat, but effort was consistently good. The test did arouse an interest in numbers and number sequences evident in other situations.

It was found that to score the results according to the Stanford-Binet method ignored all but gross steps in improvement, for various degrees of ability appeared at each level. Sometimes on the 4-digit numbers all of the digits were given correctly though not in the right sequence. Reversals were fairly numerous. The addition of an extra digit to an otherwise correct series frequently occurred. Consequently, a system of progressive values for performance was considered advisable.

Performance	Score in points
3 digits in correct sequence	1
4 of 4 digits correct (with additions or transpositions)	2
4 digits in correct sequence	3
5 of 5 digits correct (with additions or transpositions)	4
5 digits in correct sequence	5

The three best performances for each day were counted. A week's practice score consisted of an average of the three best performances on each of three days. Test scores included only the three best performances on each of two days.

C. TESTING THE ABILITY ATTAINED IN MEMORY FOR OBJECTS

Since previous work on object-memory tests for children offered little in the way of models, a test known to the children as the "toy game" was constructed. It was admittedly an exploratory project which offered possibilities of testing factors in memory other than the purely verbal. It also had the advantage of maintaining the children's interest. In spite of certain inadequacies, such as equating the objects for difficulty, results on the basis of the scoring method finally adopted were comparable with results on other memory material.

Forty-five objects which the children were able to name on sight before the experiment began were chosen for use.

Object-Memory Test

Position of objects

1. carriage
2. pennies
3. beads
4. scissors
5. clothespins
6. bird
7. glasses
8. spoon
9. mirror
10. ball
11. letter
12. tree
13. book
14. trap
15. soap
16. chair
17. pins
18. airplane
19. matches
20. key
21. laces
22. iron
23. comb
24. pipe
25. nickels
26. auto
27. knife
28. house
29. hdkf.
30. pencil
31. man
32. blocks
33. cup
34. dog
35. clock
36. bed
37. ring
38. shoe
39. string
40. horse
41. button
42. pocketbook
43. bell
44. brush
45. paper

Any desired combination of toys could be transferred quickly from a cabinet to the small table behind a screen ready for presentation. The child was seated at the table opposite E, who said, "Now I am going to show you some toys, one at a time, and I want you to remember what they are so you can tell me afterwards. Watch carefully. I'll nod my head when it's time for you to tell me." The toys were then presented in succession for an exposure time of approximately two seconds apiece. Each was removed before the next appeared. As soon as the last toy was removed, E gave the signal for recall. First, two toys were presented. If the child recalled those correctly, three were presented. If these were correct, then four were given. Only a few times were five objects tried because seldom was there success in naming four. In case the three objects were incorrect, this same number, though not the same objects, was presented again. There were no more than two trials at each level. On missing the second trial, the next lower level was presented, and so on, until the child was successful. After the first tests, the starting-point became the highest score which the child had been able to achieve in the preceding practice and continued from that point either up or down in the manner described above. Presentations for the day usually totalled five. The child saw each object about once a week; methods of choice were variable enough, however, that the object did not appear in the same constellation more than twice during the practice sessions.

Cooperation was good. Between presentations, while E was arranging the next series entirely out of sight, the subject could close her eyes, lay her head on the table, or run over to the corner until E announced it was time to come back. It was noted that this procedure which depended on the desire of the child very well took care of any natural restiveness.

After the different methods for scoring this test had been tried, the following system which gave credit for fine gradations of improvement was adopted.

Performance	Points
2 of 2 objects	1
2 " 3 "	1
3 " 3 "	2
3 " 4 "	2
4 " 4 "	3

An average of the two highest performances constituted the score for the day. By averaging three of these daily scores, the score for the week was found.

D. TESTING THE SKILL ATTAINED IN THROWING RINGS OVER A POST

The ring-throw game proved popular with both children. In this test[6] the child stood 5½ feet from a green post, 6½ inches high and 1 inch thick, set in a 12-by-15-inch white platform, also 1 inch thick. This platform in turn was placed on green linoleum with two concentric circles drawn in black as an aid in scoring the quality of performance. The first circle was 12 inches, and the second 24 inches, from the post. Instructions were given when the child was standing at the proper line. "You see the post, don't you? The game is to throw the ring *over* the post so that it goes on. Do you understand? Throw carefully and try to make it go over the post. Keep your eye on the post." Each twin gave evidence of understanding the game immediately. No instruction or assistance was offered in the course of the practice or test periods, which consisted of 20 throws, 5 at a time, before picking up the rings to repeat. Each child held the rings over her left arm and threw with the right hand. At the end of the first ten throws, E often allowed the child to change places with her, i.e., Twin *T* or *C* recorded E's performance of 5 ring throws. This technique gave the children a short rest period and, in addition, it added much to the enjoyment of the subjects for they loved to assume E's position and prerogatives. Often, in all seriousness, they would give the exact instructions for her to *follow*; in case things were going badly they admonished in E's best manner "Keep your eyes on the post."

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[6] The specifications of Goodenough and Brian were used. For a more detailed description, the reader is referred to their study.

By using a mimeographed diagram it was possible to record the approximate spot where each ring fell. Numerous scoring devices were tried. It was found that the all-or-none method of counting only the ringers did injustice to the total day's performance by omitting consideration of much of the data.[6] Consequently a point system was worked out:

Performance	Score in points
Ringer	3
Within 12-inch circle	2
" 24- " "	1
Beyond 24- " "	0

Each week's score represents the average of 60 throws computed in the manner just described. One day of each week of the practice series a child was allowed 5 extra throws if she asked for them; it is significant of the sustained interest that neither child missed these a single week.

Since in the initial tests and during the first week of practice, the final landing-spot, and not the place where the ring first touched, was recorded, it was necessary to calculate these first scores. For *T* it seemed fair to accord her the same scores attained in the second week of practice though these may easily have been too high. The difference between *T* and *C* is in the same ratio as their difference in the last retest.

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[6] Goodenough and Brian, using 20 children divided into 3 groups, decided that *ringers alone constituted the best scoring method.* Examination of their table shows that the range of value from child to child within their three groups was so wide that comparisons of individual children on this scoring scale would be meaningless.

E. TESTING THE SKILL ATTAINED IN CUTTING

To secure a measure of the child's performance and progress, graph paper was used as test material. On an 8½-by-11 sheet of 10-to-the-inch cross-section paper, two parallel vertical red lines, 6 inches high, were connected at the top by a 5-inch horizontal red line. On a second sheet of the same size a 10-inch red line, starting 3 inches down one side, was drawn across the page almost to the opposite corner where it turned at a 45° angle and proceeded straight for 7 inches.

The task on these sheets was designed to test fine motor coordination necessary to stay on a line. Scoring was simple. It consisted of counting the number of cross-section squares or fractions of squares between the red line and the cutting. Deviations for the two materials were averaged to give a daily score. The score for the week was determined by averaging these daily scores.

A second part of the cutting experiment was designed to test the degree of error involved in cutting corners. At this age it is sometimes difficult for the child to stop the scissors at exactly the right place in order to make the turn; either she stops short or goes beyond. Material for the test was a half sheet of the graph paper on which was drawn a series of 1-inch red stair steps. To score, one had only to count the numbers of three-millimeter squares or fractions of them above or below the turning-point of the red line. For a weekly score the performances for three days were averaged.

As the experimenter indicated the starting-point, the child was told to cut as carefully as possible along the lines. On the stair steps, it was explained that special care would be necessary at the corners in order to stay on the red line. After the children became familiar with the material they were allowed to choose which drawing was to be cut first. Sometimes they guessed which one the experimenter held hidden for the next presentation.

At the end of each testing, E had the child show her the places which were best done. In this way attention was focused on the kind of performance which was considered desirable. The children adopted various names for the drawings. The figure with parallel lines was usually a house. After cutting a doorway the house could be made to stand up. Sometimes windows were drawn, and various decorations added. The second figure became a wall or sidewalk while the stair-step figure most frequently was called a church. Both children liked to draw the people who lived in the house, passed on the walk, and attended the church.

F. TESTING THE SKILL ATTAINED ON THE WALKING-BOARDS

This test involved the use of three walking-boards, 2, 4, and 6 centimeters in width, 250 centimeters in length, and 10 centimeters in height from the floor. At each end of the board a small square platform made it possible for the child to stand flush with the board ready to start; it also enabled her to balance both feet at the end before jumping down. As the child stood on the small platform ready to start, the experimenter said, "See this board. I want you to walk on top of it way to the end. If you step off, step right back on again at the same place and keep on going until you get to the end. Do you understand? . . . . Ready, go." Time was taken from the second the child's first foot touched the board until both feet were placed on the platform at the other end. Board 6 was always given first, then board 4, and finally board 2, with three trials on each board before the next was introduced. For each trial, errors as well as time were noted. Since each board was given 3 times a day with practice periods spaced 3 times a week, performance for a week consisted of the average of 9 trials on each board. In plotting the learning curve for the eight weeks of practice, each of the eight points therefore represents 9 trials either in terms of time or errors. During the four-week intervals when testing alone took place each point is based on 2 tests of 3 trials per board, or a total of 6 trials.

In view of recent experimentation by Courtney and Johnson (4) on the difference in emotional response of children to the walking-boards and the effect of this factor on performance, it may be noted that each twin had the very healthy attitude of try-and-try-again with no signs of fear at any time. Comments by the children in reference to their experience on the walking-boards give a picture of enjoyment and cooperation for practically every session. To get some objective measure of this interest during the practice period an extra trial per week on each board was granted upon request of the child. During the eight weeks *T* asked for all 8 extra opportunities on board 6 as well as on board 4, but only 6 on board 2. *C* had 7 on board 6, 7 on board 4, and 5 on board 2; since she had neglected to ask during the first practice week her total number automatically was lowered. These figures do indicate how spontaneous interest persisted to the end.

Proficiencies attained on all tests are summarized in Table 3.

V

PRESENTATION AND DISCUSSION OF RESULTS

A. Digit-Memory

Results of test sessions and practice periods are presented graphically in Figure 1. On the initial tests in January a slight unreliable superiority for *C* is evident. Practice for eight weeks increases this superiority until on Retest I in April, *C* has risen from 1.3 to 3 points while *T* has remained at the initial test level of 1 point. As soon as *T* is subjected to intensive practice, however, she immediately improves until she totals 3.7 points on Retest II in June. Reference to the scoring system will show a score of 1 to mean 3 digits, a score of 1.3 to mean 3 plus digits and the final scores of 3 and 3.7 being 4 and 5 digits, respectively.

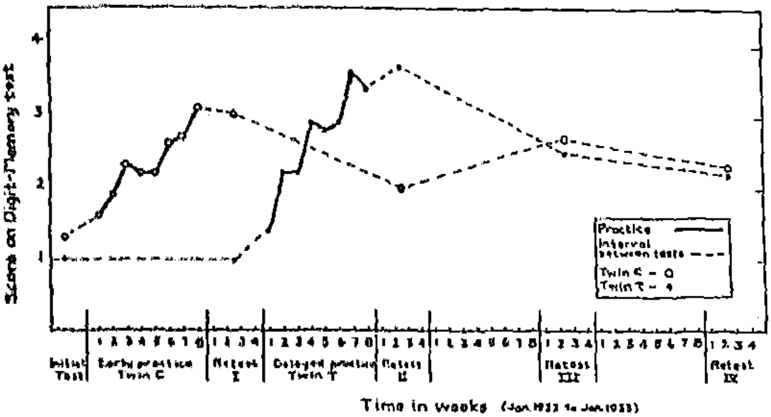

FIGURE 1
Digit-Memory

On the Stanford-Binet test, a score of 3 digits is a 3-year performance, 4 digits a 4-year, and 5 digits a 7-year performance. Hence the total improvement during the second practice period of 8 weeks corresponds to a 4-year gain on the Stanford-Binet.

As a result of *T*'s practice during the second period, *T* and *C* have reversed the positions which they held on the Retest I; the practice curve and the non-practice curve have cut across each other. Not only has *T* greatly improved but *C*, with no practice, has been unable to maintain the position which she gained as a result of intensive practice. In September, after a three-month interim of non-practice, both children give almost identical performances. With the cessation of practice, *T* has shown the decline in performance which *C* exhibited under the same circumstances, so that the performances are as similar as on the initial tests. The final check in December continues and confirms the September results.

In a comparison of the two practice periods it is evident that, though *T* and *C* started with approximately the same performance, the curves of memorization show certain distinct characteristics. Most *outstanding is the plateau of C which lasts from the* third to the sixth week. Analysis indicates highly consistent records of success on approximately 2/3 of the 4-digit numbers. Not until the sixth week, however, when a rise in the curve is again evident, was *C* successful with a 5-digit series, and in each of the two following weeks she gave a 5-digit number correct except for sequence. It would appear that the plateau was maintained until *C* was able to achieve the 5-digit series.

While *C* did not attain 5 digits until the sixth week, *T*, whose curve of memorization by contrast seems to rise abruptly, was successful on a 5-digit series at the end of the second week. She achieved two successes during the fourth week, one success except for sequence in each of the fifth and sixth weeks, three successes in the seventh week, of which two were in correct sequence, and two entirely correct in the last week. At the same time *T* was constantly improving her performance in the 4-digit series until in the seventh and eighth weeks she received scores only for performances on or above the 4-digit level.

The early practice of *C* resulted in an advance of 1.7 points, while T, who received practice 12 weeks later, gained 2.7 points. Handicapped by her inability to master 5 digits, *C* remained on a plateau for several weeks. This may have been an individual matter or it may actually have been due to a difference in age. However, caution should be exercised in attributing the greater gain to an added maturity since the results hinge on one curve of memorization.

The results of this experiment confirm those of Gates and Taylor (9) on the effect of intensive practice on oral digits. They found that after 78 days of practice during 4½ months on memory for digits, the practice group had gained 2.07 digits, the amount gained by the average untrained child in six years according to the Stanford-Binet test. The control group had gained .73, or one-third as much. On the retest

4½ months later the advantage of the practice group had been entirely lost and the two groups were as nearly equal as at the beginning of the study. As an hypothesis, Gates and Taylor suggest that this transitory improvement was "wholly in the form of devices, information, adjustments to the test conditions, 'tricks of the task.'" In connection with this hypothesis, the greater advance of Twin *T* who received the delayed practice may be of significance since both twins were given the practice by the same experimenter under precisely the same experimental conditions. The probability of their developing similar adjustments to test conditions is not only great but is borne out by observations of the experimental sessions. The greater gain of the second twin therefore is important. Its interpretation can better be postponed until the improvement in other functions has been analyzed.

B. OBJECT-MEMORY

Results obtained on the object-memory test are presented in Figure 2. The initial scores in January of 1.25 for *C* and 1.50 for *T* indicate similarity. With eight weeks of practice, *C* improved her performance on Retest I in April to 2.0 points, while *T* remained exactly the same during this period. Delayed intensive practice for *T*, however, produced an acceleration which culminated in a score of 2.75 on Retest II in June. As in the digit series, delayed practice resulted in a reversal of the previous retest situation, with *C* now lower than *T*. On the October retests, after three months of non-practice, the twins again exhibited very

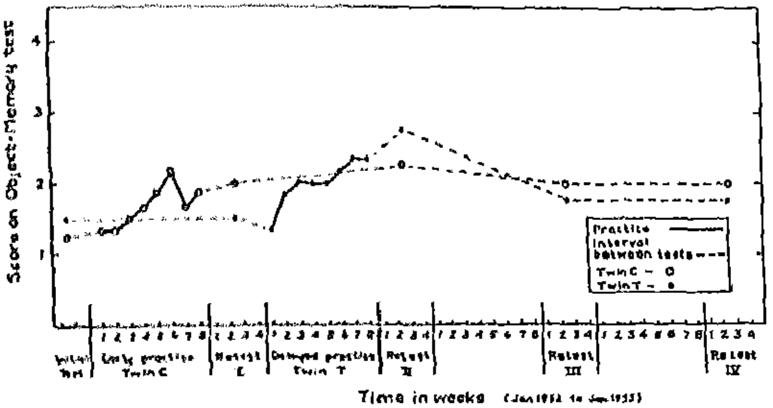

FIGURE 2
Object-Memory

similar performances. During the interval *T*'s performance had dropped from its June peak of 2.75 points to an October level of 1.75, a score which also prevailed in the December tests. *C* had steered a steady course from her score of 2.0 points on Retest I in April after special practice, to 2.25 on retest in June, to 2.0 in October, and 2.0 in December. The consistency of these retest scores indicates that the upward trends of the practice periods are all the more significant.

Comparison of the practice periods shows curves of memorization which are quite different for the two children. While both do about equally well during their first week of practice, *T* jumps ahead in the second week to a point above *C*'s fifth week. Greater consistency in memory for 3 objects, combined with an earlier appearance of memory for 4 objects, constituted *T*'s superiority. She succeeded on 4 objects in her eighth practice session and repeated this success in sessions 10, 12, 14, 17, 19, 21, and 22. The plateau during the fourth and fifth weeks was probably related to the initial abrupt rise. Another plateau in the eighth week proved of short duration, since on the retests two and a half weeks later considerable improvement occurred. In contrast to *T*'s spurts and plateaus, *C* climbs steadily though slowly to the sixth week. It was not until this week in the sixteenth practice session that *C* succeeded on the 4 objects, with subsequent success only in the eighteenth session. Because *C* did better in this sixth week than in either the seventh or ninth weeks of practice, there was reason to believe that scores for these weeks might not be typical. Notes during the seventh week revealed that at one of the sessions, due to a previous hour in another experimental situation at the clinic, *C* was tired and inattentive. On another day of the same week the mother visited the clinic, with the result that both children were noisy and restive. In the eighth week, after a period in another experiment, a less satisfactory performance again followed.[7] These facts explain why scores for the sixth practice week were higher than scores for the seventh and eighth weeks and higher than the retest scores in March. No further loss was evident with the cessation of practice, possibly because the effect of the practice was already diminished during the last quarter of the period.

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[7] These same circumstances seemed to exert much less effect on digit-memory. Observations throughout the experiment bear out the statement that object-memory requires more concentration and attention and is more easily affected by fatigue than the rote task of repeating digits.

Because of the decline in *C*'s performance before the end of practice, no valid comparisons of the total gains for the two practice periods are possible, although the qualitative analysis above shows an earlier development of memory for 4 objects, and points to superior performance in the delayed-practice twin.

Verbalization at subvocal levels, of course, could not be determined but it was possible during the presentation of objects to note the extent of visible lip movements. *C* was first seen whispering the names of the objects at the ninth practice session, again at the tenth, fourteenth, sixteenth, and eighteenth. *T* began somewhat later, in the fourteenth session, and continued in the seventeenth, nineteenth, twentieth, and twenty-second. To keep conditions as uniform as possible when verbalization was noted, the experimenter would comment, "You can wait until you've seen all the objects to tell me what they are." Beyond this nothing was done to discourage the practice. Certainly, verbalization remained a sporadic occurrence, never became a habit. The quality of performance with which it was associated was high.

A comparison of results on digit-memory and object-memory necessarily takes into account the difference in procedure and methods in the two tests. For example, duration of the visual stimulus was longer for the objects than the auditory stimulation afforded by the digits; length of interval between digits is known to affect memorization. Different digits were more comparable for use as units than were the various objects. Recognizing many limitations, however, certain broad comparisons are possible. One of the most outstanding of these is the difference in level of performance. In digits a series of 3 constituted the basal performance; a series of 5 in correct sequence constituted the best. Objects proved more difficult. The basal performance was a series of 2, and the best was a series of 4 objects in any sequence. When 5 objects were given, neither child was able to achieve more than 3 of them, with the majority of responses under this level. Since no directions were given for repetition of objects in correct sequence, as in the case of digits, sequence in objects was not scored. Correct sequence for the 3 objects composed 30% of *C*'s responses, 37% of *T*'s. For 4 objects, *C* did not get either of her two successes in correct sequence while *T* repeated 33% of hers in correct forward sequence and 33% in exactly reversed sequence.

Results obtained on memory for stories where both children were given simultaneous practice may be compared with results obtained on object-memory and digit-memory where Twin *T* was given practice three months later than Twin *C*. Differences in the length of practice period between the two experiments are recognized. Nevertheless it may be significant that simultaneous practice produced marked similarity. Each twin was ahead of the other on 3 of the 8 days, and on the rest they were alike. In digit-memory, delayed-practice Twin *T* leads in 6 of the 8 weeks of practice. In object-memory, delayed-practice Twin *T* leads in 6 of the 8 weeks and the scores are tied in the other 2 weeks.

C. Ring-Toss

A comparison of the learning curve for the ring-toss with the memorization curves which have just been presented reveals that motor and memory functions may behave in characteristic, common ways. Again it is evident (Figure 3) that, though *T* and *C* were similar in ability on the initial and final tests, special practice in the meantime produced considerable acceleration. Practice for *T* over the first 8-week period resulted in a score of 38.5 on Retest I in April. This score was a gain of 8.5 over the initial test score. While the control twin in the memory experiments main-

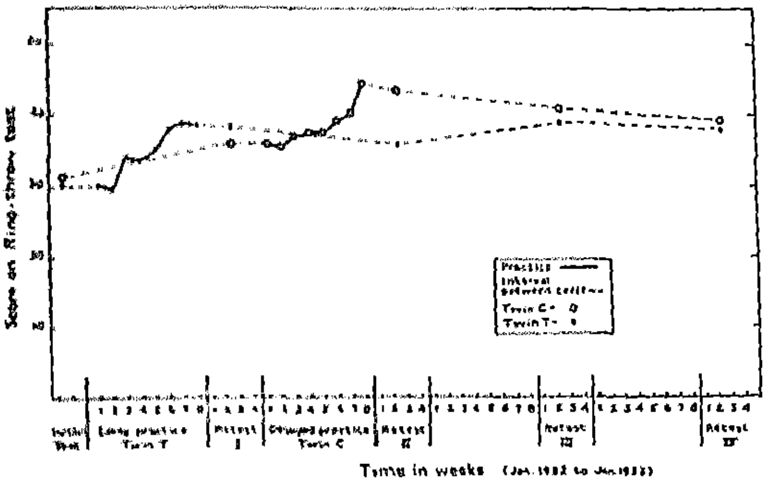

FIGURE 3
Ring-Throw

tained the same level of performance on initial and first retest scores, Twin *C*, who was the first control in the ring-toss, rose from an initial score of 31.2 to 36 on Retest I. The difference between *T* and *C*, therefore, in this first retest was slight. After the second 8-week period, however, when *C* was given the special practice, she achieved a decided superiority. On Retest II in June, which followed her practice, she scored 43.5 compared with *T*'s 36.0. As in the memory experiment, cessation of special practice meant some loss of skill. After the first practice period for *T*, her non-practice curve on its downward swing crossed the upward curve of practicing *C*. After the peak attained with special practice, *C* also declined in skill so that on the retest three months later she and *T* were similar in ability. A further retest three months after this showed the twins to be maintaining consistent relative positions.

Because *T*'s score for the first week of practice had to be calculated from partial data, second-week averages are used for comparison with the eighth-week to give an idea of total gains during the respective practice periods. We find that both children gained similar amounts, 9 points for *T* and 8.6 for *C*. It may be *C*'s initial improvement without practice which limits her gains during the special period. Probably the climb from an upper level of 35.7 to 44.3 is more difficult than that from 29.7 to 38.7. If total gains over the initial test scores are calculated, *T* has gained 8.5 and *C* has gained 13.1. While *T* made her improvement by two rapid spurts followed by plateaus, *C* gave a flatter, and for the most part positively accelerated, curve. Analysis of the practice sessions indicated very little which might account for the individual character of the curves, except, of course, that *C* started at a higher point. The twins used very similar techniques in throwing, although *T* seemed to throw a little faster and higher.

Twin *C*, who received the delayed practice, scored a higher average on all of the eight weeks of practice than did Twin *T*, who received the early practice. This is consistent with the results on digit-memory and object-memory, where the twin who received the delayed practice gave a superior performance.

That superiority may be a function of the method of scoring finally adopted can be seen by consulting raw scores for each of the practice weeks presented in Table 4. If number of ringers alone had been scored, Twin *T*, who received the early practice, would have led in six of the eight weeks and tied in one of the other weeks; Twin *C* would have been ahead only on the last week. From Table 4 it is clear that the average number of ringers per week fluctuated around a point; no general trend during the practice periods was demonstrable. On the other hand, definite tendencies toward proficiency with practice are clear in the movement of ring-throws from the outer zones toward the central position of the post. This was one reason for accepting the zoning method for presentation and more detailed discussion.

TABLE 3
SUMMARY: PROFICIENCY ON WALKING-BOARD, RING-TOSS, CUTTING, OBJECT-MEMORY, AND DIGIT-MEMORY TESTS

	Initial test averages Jan.		*Average weekly proficiency in 1st training period*								*Retest 1 averages April*	
	T	*C*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*T*	*C*
Walking-boards						*T* is practiced						
II (Errors)	7.5	7.8	6.9	7.0	6.1	5.8	4.7	5.2	6.2	3.0	5.9	6.7
IV (Errors)	4.0	4.0	2.0	2.5	2.8	1.6	2.0	1.4	2.2	2.0	1.0	3.2
VI (Errors)	.8	2.3	.7	.7	1.1	.3	.2	.4	.6	.7	0	.6
II (Time)	28.5	27.8	18.9	16.5	17.7	16.9	16.1	15.0	18.7	15.2	17.6	20.7
IV (Time	20.0	20.2	12.1	12.9	12.9	12.3	12.4	12.0	12.3	9.6	10.2	13.2
VI (Time)	13.2	17.6	10.2	8.1	10.2	7.0	5.7	4.7	6.6	5.0	7.0	12.2
Cutting						*C* is practiced						
Straight	131.5	159.0	100.3	41.7	23.8	22.1	19.0	10.9	15.7	11.2	37.7	6.4
Corners	31.5	27.5	22.5	15.7	17.5	8.8	9.2	5.0	4.7	3.5	11.0	5.0
Ring-throw						*T* is practiced						
Data	30.0	31.2	30.0	29.7	34.0	33.7	35.0	38.0	39.0	33.7	38.5	36.0
Digit-memory						*C* is practiced						
Data	1.0	1.3	1.6	1.9	2.3	2.2	2.2	2.6	2.7	3.1	1.0	3.0
Object-memory						*C* is practiced						
Data	1.50	1.25	1.33	1.33	1.50	1.67	1.83	2.17	1.67	1.83	1.50	2.0

Average weekly proficiency in 2nd training period 1	2	3	4	5	6	7	8	Retest II averages June *T*	Retest II averages June *C*	Retest III averages Oct. *T*	Retest III averages Oct. *C*	Retest IV averages Jan. *T*	Retest IV averages Jan. *C*
		C is practiced											
6.6	5.7	5.1	4.2	5.0	5.2	3.6	3.1	3.7	3.3	3.0	3.5	3.7	4.4
2.7	2.6	1.8	1.1	2.1	1.5	1.1	.9	1.0	.3	1.0	1.3	1.2	.8
.6	.2	.4	.3	.3	.3	.1	.3	.15	.15	0	0	0	.15
19.2	20.6	18.7	11.3	15.4	13.1	12.6	11.0	12.5	10.1	8.8	13.5	13.8	11.2
17.1	16.9	16.4	8.4	9.9	8.9	7.5	7.4	7.7	7.7	8.0	9.8	11.0	10.5
14.5	13.6	10.2	7.0	5.9	6.0	6.4	4.8	5.5	5.3	6.3	8.45	7.9	9.3
		T is practiced											
25.3	32.9	44.4	31.2	27.7	22.6	23.5	17.4	27.2	11.3	15.5	7.7	11.5	5.7
6.8	5.7	4.8	4.2	5.8	5.2	3.8	3.2	3.8	3.5	2.5	1.2	1.8	2.4
		C is practiced											
36.0	35.7	37.0	37.7	37.7	39.3	40.3	44.5	36.0	43.5	39.0	41.0	38.0	39.5
		T is practiced											
1.4	2.2	2.2	2.9	2.8	2.9	3.6	3.4	3.7	2.0	2.5	2.7	2.2	2.3
		T is practiced											
1.33	1.83	2.0	2.0	2.0	2.17	2.33	2.33	2.75	2.25	1.75	2.00	1.75	2.0

TABLE 4
RING-TOSS: RAW SCORES DURING PRACTICE PERIODS

Weeks of practice	Ringers	Zones I	Zones II	Zones III	Weighted score
Twin T					
I	6	?	?	?	30.0?
II	9	17	28	6	29.7
III	7	30	21	2	34.0
IV	6	35	13	6	33.7
V	5	36	18	1	35.0
VI	7	40	13	0	38.0
VII	7	46	4	3	39.0
VIII	6	44	10	0	38.7
Twin C					
I	5	38	17	0	36.0
II	5	37	18	0	35.7
III	7	40	10	3	37.0
IV	3	48	8	1	37.7
V	4	45	11	0	37.7
VI	4	51	4	0	39.3
VII	4	53	3	0	40.3
VIII	12	48	1	0	44.3

D. CUTTING

It will be noted at once in Figures 4 and 5 that cutting presents certain characteristics which differ from

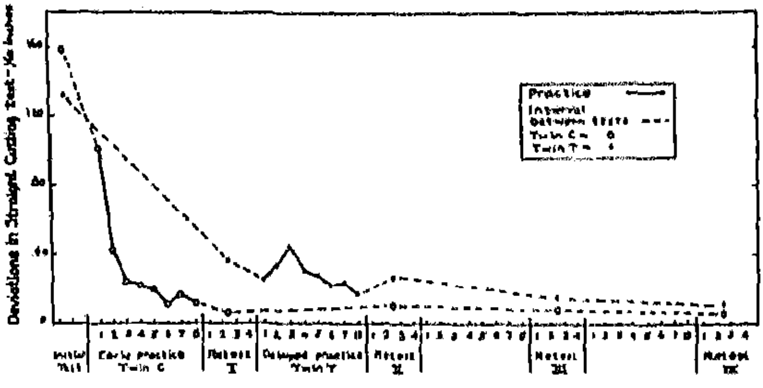

FIGURE 4
STRAIGHT CUTTING

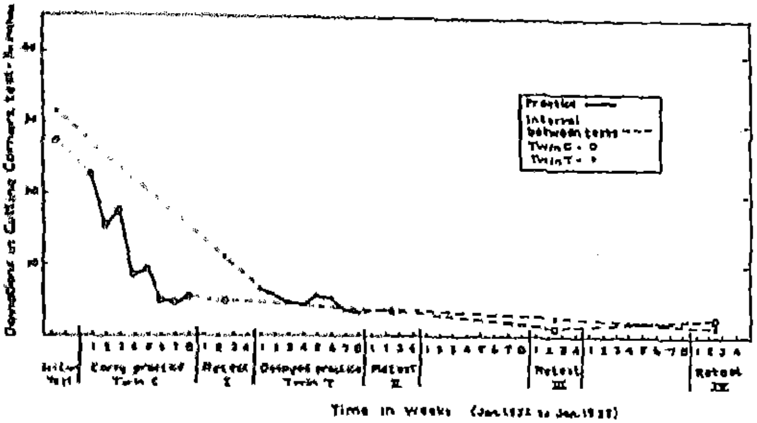

FIGURE 5
CUTTING CORNERS

those in the preceding curves. By choosing a fairly well-advanced ability (22, 31), yet one which showed great room for improvement on the initial performance, it was possible to test the nature and stability of improvement occurring in conjunction with greater *maturity*.

Though both children deviated greatly from the lines (Figure 4) in the initial tests, improvement was exceptionally rapid. From a test score of 159, *C*, who was given practice first, dropped to an average of 100.3 for the first week of practice, to an average of 41.7 for the second week, and to a test score of 6.4 by the time of Retest I in April. From an initial test score of 131.5, *T*, who had received no practice during this period, had improved her score to 37.7 at the time of Retest I. By Retest II in June, after eight weeks of practice, she scored 27.2. *C*'s scores on the June, October, and December tests are so similar to her April one that the curve here approximates a straight line. *T* also shows no loss of skill on succeeding retests. It will be recalled that in digit-memory, object-memory, and ring-toss, an interval of no practice was followed by a decline in the specific ability.

Neither T *nor* C *loses any of the skill which they attained as a result of the special practice in cutting.* It would appear that practice in a more completely matured ability is not only economical but has more lasting effects.

A comparison of amounts of deviation for *T* and *C* (Figure 4) shows a marked superiority for *T* in the practice period and on all tests except the first. This difference in scores is a reflection of the difference in the approach of each child. Where *C* cut slowly, carefully, and by short mincing steps, *T* often used the whole length of the scissors on a cut and thus set a much faster pace. When both children were timed during an October retest, *C* spent 215" to *T*'s 97" on the parallel-line structure. *C* required 195" to *T*'s 70" on the step-like structure.

The results for cutting corners are graphically presented in Figure 5. While *T* was consistently better than *C* in terms of deviation (Figure 4), she does not keep this advantage when cutting corners. *T*'s rapidity, which proved a handicap in terms of deviations, did not penalize her here. Though often cutting up to a corner with but one incision, her estimations proved very accurate. The same important trends which appeared in connection with cutting scored in terms of deviation from a line are evident in the ability to cut corners: a tremendous initial improvement followed by no losses in skill after special practice has ceased.

The form of the curves obtained in this experiment may be compared in a general way to the form of the cutting curve obtained in a previous group investigation on younger children by the author (22). Exact comparisons are impossible since the units of measurement were adjusted in order to conform to the requirements of a younger age group, where some of the children could only cut gashes. It will be recalled that the age of the subjects in the group experiment was 2½ years, an average of 2 years younger than the twins. The most striking characteristic revealed in a comparison of the studies is the contrast in rate of improvement. The learning curve of the earlier age group shows linear and slight negative acceleration compared with pronounced negative acceleration evident in the twins. Improvement without practice appeared in both experiments.

E. WALKING-BOARDS

Complete data on the three walking-boards are presented in Table 3. Proficiency in terms of errors is given graphically for boards 2 (centimeters) and 4 (centimeters) in Figure 6. This figure is not complicated by the inclusion of data from board 6 because from the very beginning paucity of errors on this board permitted no differentiation with practice. Though error and time scores are clearly related, scoring by errors was better because the amount of error connected with each board differentiated it at all times from the other boards. That is, no overlap in performance on the various boards was evident; proficiency on board 2 always involved more errors than on board 4, and proficiency on board 4, in turn, always involved more errors than on board 6.

Time differences between boards were more easily bridged. Scoring the largest board of 6 centimeters in terms of time, however, was preferable to scoring it in terms of errors, for there was always room for improvement in the time score.

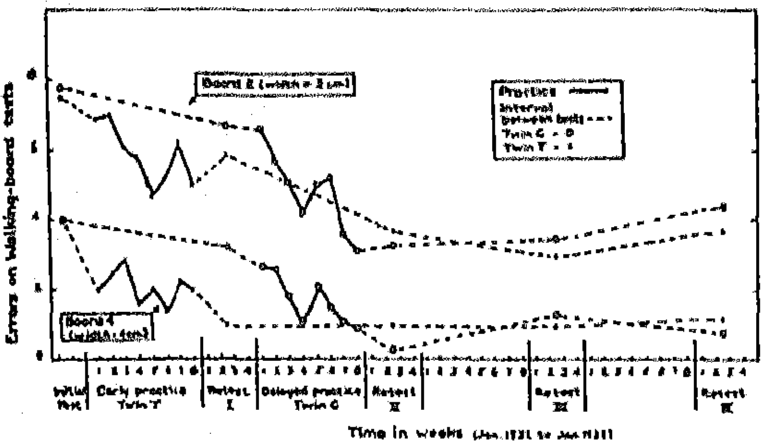

FIGURE 6
ERRORS ON WALKING-BOARDS

Performances in terms of error scores on board 2 (Figure 6, upper half) will be given detailed consideration. The twins were well matched on initial performance. With an initial test score of 7.5 errors, *T*, who receives the practice during the first eight weeks, lowers her score to 5.9, making 1.6 fewer errors. *T*'s score is .8 error better than that of *G* who has also gained during this time. After the second practice period, when *C* has received the practice, she becomes more proficient than *T*, so that delayed practice has reversed the relative standing which prevailed after the first practice period. *C*'s errors as a result of the practice have dropped from 6.7 to 3.3, or 3.4 fewer errors. Not only has the practice twin improved, but *T*, as the control during delayed practice, has bettered her score from 5.9 to 3.7, or 2.2 fewer errors, so that the performances of both children are similar in this retest, as they are in the subsequent retests at three-month intervals.

The irregularity in each practice curve is its most striking feature. The increase in errors from the fifth to the seventh week for *T* and from the fourth to the sixth week for *C* are to be accounted for. In order to further this analysis the time curves are presented for the same board (Figure 7). Examination of these

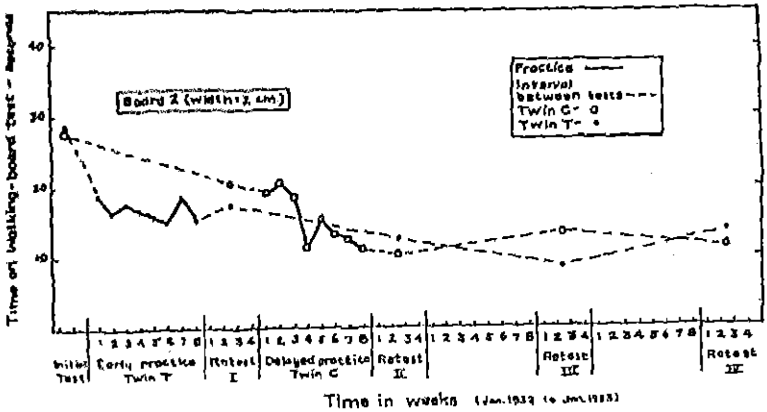

FIGURE 7

TIME ON WALKING-BOARDS

time curves shows that the increase in errors comes usually with an increase in time. Notes by the experimenter indicated poorer performances when the children were extremely cautious. Though a decrease in errors was always associated with a good time performance, a good time performance did not always mean a decrease in errors.

Attention may be called to the greater gain of the delayed twin. During the first practice period *T* reduced her errors from 7.5 to 5.9, or 21%. Since she had shown a greater skill during the fifth week than in the subsequent weeks of her practice period and retest, this percentage of improvement may not do entire justice to her ability, though her maximum gain (in the fifth week) was 37%. During the second practice period *C* reduced her errors from 6.7 to 3.3, or 50%. This retest score is similar to her best performance during the practice period. If average scores for each of the practice weeks are compared for Twins *T* and *C*, it will be seen that Twin *C*, who received the delayed practice, leads her sister in 6 of the 8 weeks and ties the score in another week. Thus we see the consistent advantage again in favor of the twin who received the delayed practice.

Associated with the gains of the practice twin are gains by the control twin, evident at the close of both practice periods. During the first period, control *C* makes 62% as much improvement as practiced *T*, while during the second period control *T* makes 65% as much as practiced *C*. Reduction in errors on this test proved relatively stable with very little loss of skill taking place within the period of study.

Board 4 (Figure 6, lower half) shows many of the characteristics noted in connection with the discussion of board 2. The early practice curve of Twin *T*, however, is quite different. Reduction by 2 errors between initial test and initial practice is the greatest improvement Twin *T* ever makes. The learning curve for the delayed-practice Twin *C*, on the other hand, bears a close resemblance in form to her curve on board 2 which has just been discussed. In general, the relationship which the performances on the boards bear to each other in the degree of proficiency for any one week is great. Improvement often takes place in the same direction on each board. For example, rapid progress during the fourth week of the second practice period is evident on both board 2 and board 4. If the time curves for the same practice period were available they would show an even more striking parallel of progress on all boards. Apparently there are general factors affecting all the performances on any given day.

It was hoped that the various grades of difficulty which the walking-boards presented might give information regarding the relationship of degree of difficulty to the shape of the learning curve and also indicate whether degree of difficulty might be related to loss or gain after intensive practice had ceased. Mattson (28), it will be recalled, related learning and retention to complexity of task as measured by performance on a simple maze, an intermediate maze, and a complex maze. These results suggest a parallel comparison of degree of difficulty on the walking-boards.

Degree of difficulty may be related to the amount of initial improvement. This is shown by reference to the learning curves of Twin *T* on boards 2 and 4 (Figure 6). We know by consulting the time curves for boards 6, 4, and 2, as well as the error curves for boards 6 and 4, that Twin *T*, the first trained, has a characteristic curve of learning that shoots up rapidly during the first week of practice and then gains very little in subsequent weeks. In spite of this characteristic curve on all other items, Twin *T* on the *most difficult* performance is able to make but slight improvement for the first two weeks and, in general, presents quite an atypical curve. This evidence may or may not be indicative of an underlying principle. Certainly it constitutes an hypothesis well worth considering for further experimentation. It was not possible to relate loss or gain in proficiency after intensive practice to degree of difficulty.

F. RECAPITULATION

Results of early and delayed practice are given in Table 5. Inspection of this table shows that:

1. Early practice of 8 weeks resulted in superiority for the practiced twin on all test measures except the time score of the largest walking-board, where the children were not well matched in the initial tests.
2. Delayed practice (12 weeks later) for 8 weeks resulted in superiority for the delayed-practice twin in

TABLE 5

COMPARATIVE SUMMARY OF RESULTS

+=yes
—=no
0=similar
?=ambiguous

	Memory		Cutting		Walking-boards 2	4	6	2	4	6	Ring-toss
	Digit	Object	Deviations	Corners	Errors	Errors	Errors	Time	Time	Time	Score
Early practice results in superiority for practiced twin	+	+	+	+	+	+	+	+	+	0	+
Delayed practice results in superiority for practiced twin	+	+	—	0	+	+	0	+	0	0	+
Greater gain during delayed practice period	+	+	—	—	+	0	—	0	—	+	0
Gain by control during early practice period	—	—	+	+	+	+	+	+	+	—	+
Loss with cessation of practice after early practice period	+	?	—	—	—	0	—	—	—	—	+
Loss with cessation of practice after delayed practice period	+	+	—	—	+	0	—	—	+	+	+
Similar performances 3 and 6 months after practice	+	+	+	+	+	+	+	+	+	+	+

object-memory, digit-memory, ring-toss, errors on boards 2 and 4, and time on board 2. With the exception of errors on board 4, these represent performances where the degree of improvement still possible is large. Delayed practice resulted in similarity of scores for practice and control child on cutting corners, on errors on board 6, and time on boards 4 and 6. These are performances which rapidly approximated or were already near maximum. In deviations in cutting, an individual technique produced consistent variation.

3. Greater gain by the delayed-practice twin within the practice series was, as a rule, inversely related to the gain which that twin had made as a control during the early practice series. This is easily understandable. In memory for objects and digits, where the control made no progress during the early practice period, all of the subsequent improvement took place *within* the delayed practice period itself. In cutting, where the great gain of the first control twin resulted in scores near the maximum, it was obviously impossible to improve as much in the delayed as in the early period.

4. We find loss occurring after the cessation of the early practice series in digit-memory and ring-toss, with an ambiguous result in the case of memory for objects. Not only did few tests show loss but certain of the walking-boards showed a small gain by the time of the retests 12 weeks later. After the delayed practice period, loss was evident in object-memory, digit-memory, ring-toss, time on boards 4 and 6, and errors on board 2. Thus at the end of each practice series,

with the exception of the walking-boards, the same tests exhibited a decline. Cutting showed no loss after either practice period.

5. Three and six months after all practice had ceased, the performances of the children on *all* tests were as similar to each other as at the beginning of the experiment.

VI

INTERPRETATION

In this type of experimental comparison of the general developmental and special practice factors which influence proficiency, two findings are commonly advanced in favor of the importance of the more general maturational or developmental factors: (1) that at a greater age there is greater improvement with practice, and (2) that, in spite of advanced attainment with intensive practice, there is a return after cessation of practice to the normal age level, i.e., to a performance equivalent to that which would have been reached without the special practice. These two factors have been discussed somewhat in relation to the present experiment and to others in the literature. They are of sufficient theoretical interest to be given closer scrutiny in order to see what experimental conditions may be effecting alterations in performance. The greater improvement with delayed practice will be analyzed first; an analysis of behavior after cessation of practice follows.

DELAYED PRACTICE VS. EARLY PRACTICE

Greater improvement during delayed practice occurred on the following items: digit-memory, object-memory, ring-toss, and walking-boards of 2, 4, and 6 centimeters scored in terms of errors. To what factors is this greater improvement due? It may be due to (1) individual differences, (2) practice, (3) better adjustment to the experimental situation, and (4) maturational or intrinsic growth factors.

1. *Individual Differences.* Watson (35) has criticized the method of co-twin control from the standpoint that the twin who is given delayed practice may have been superior. Since in the present study each child was used both as control and as practiced subject in different functions throughout the experiment, this criticism becomes less applicable. That Twin *T* was inherently superior in just those activities which she practiced last, while Twin *C* was inherently superior in just those activities which she practiced last, is extremely unlikely.

2. *Practice.* In the present experiment there is the possibility that additional specific practice and spaced practice may be influencing the results. Before the delayed intensive practice period, the delayed twin had the advantage of two extra sessions (Retest I) given *three months after the original tests.*

The importance of spaced practice has probably been underestimated. For example, in the Hicks and Ralph maze experiment (21), improvement of the control group tested at the beginning and end of an eight-week period was interpreted to indicate the presence of maturational plus general practice factors. Of the total gain of 7.2 points made by the practice group, 4.2 came during the first week of practice. The spaced practice involved in securing the final score for the control group may have resulted in a significant portion of its gain of 8.2 points. Thus some of the gain which Hicks and Ralph attribute to factors outside the experimental situation may have been a function of spaced experimental practice.

Analysis of data in the present experiment shows very little effect of the spaced practice or of extra trials. Their presence should normally be shown by a cumulative effect during the first week of delayed practice; a decided increase in score for the first week of delayed practice over the score for the first week of early practice should occur. An appreciable increase is found only in scores for cutting. That the factors under consideration do not account for final achievement in delayed practice is evidenced by the fact that cutting is one of the few experiments in which delayed practice does not lead to superiority.

Incidental practice which occurred in related activities during the experiment may be considered negligible in its influence compared with the experimentally controlled practice. This is substantiated by the fact that the control subject gains much less than the practice subject during early practice, and there is commonly a loss after intensive practice.

3. *Better Adjustment to Experimental Conditions.* Because of the previous practice on other items, delayed-practice Twin *T* or *C* had the advantage of greater familiarity with the experimenter, the room, and general routine. It will be recalled that Gates and Taylor felt that their results on tapping and digit-memory justified the assumption that improvement with practice was due not only to better techniques of work but to better adjustment to test conditions. It is possible that this general adjustment to experimental

conditions may constitute a disturbing and unaccountable factor in early- and delayed-practice experiments. In early and delayed practice in the acquisition of language, Strayer (30) says of the control twin, "During the time spent with her, many of the same games which were played with her twin were played with her, except that they were silent." The familiarity of the delayed-practice twin with these informal games, however, may have made the names of objects connected with the games easier to fit into the child's vocabulary later. In the present experiment there is no way of knowing how much this factor of general adjustment may have facilitated progress. At least it did not show up in the early trials.

4. *Maturation.* The term "maturation" may be conceived as referring to intrinsic growth factors.[8] The superiority of the delayed-practice twin does not seem to be accounted for entirely in terms of individual differences, spaced and incidental practice, or in better adjustment to the experimental situation. However, to assign any specific proportion of the increment to maturational or growth factors is impossible on the basis of the data available. The facts are that at the time of delayed practice the practicing twin is older and profits more by practice than did her younger sister. While becoming older she was undergoing the different experiences already discussed. She was also

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[8] Marquis' distinction (27) between intracellular, intercellular, and external environment is a nice logical formulation. For purposes of experimental manipulation we have control only over certain factors of the external environment.

growing. The application of experimental findings such as these to clinical or educational practice does not rest upon the interpretation of the gains with delayed practice as being due primarily to maturational factors. The experiment does show the specific conditions under which gains can be expected.[9]

RETURN TO THE NORMAL LEVEL AFTER CESSATION OF PRACTICE

The loss of skill after experimental practice is well attested by experiments on forgetting. Hence the loss reported in this and other experiments does not in itself offer crucial evidence regarding maturation. The fact, however, that *both twins "forgot" to the same level in spite of their different attainments with practice does point to the importance of general developmental factors.*

No loss of skill in cutting appeared after either practice period. By the first week of early practice, the practice child had made marked improvement, and by Retest I the control, who had received no practice, had made even more improvement. It is apparent that even the limited *practice* of the control was of primary importance; the underlying factors were developed so that only a small amount of practice was necessary to perfect skill. At an earlier age level, where these underlying factors presumably were not developed, much less improvement with practice occurred (22).

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[9] Speculation regarding the physiology of maturation is interesting, but the experiments reported give no evidence for one hypothesis as against another.

A point to be noted is that substantial gains by the control, without practice, are accompanied by relatively stable and permanent gains by the practice child. For example, the greatest gain by the control in any of the performances studied takes place in cutting; there is no loss at all after cessation of practice. The reverse also seems to hold true. There was no gain by the control child in digit-memory, and the greatest loss with cessation of practice was sustained in this function.

This type of experiment is useful for checking the value of items in developmental schedules. Such standardized schedules assume relatively stable performances at different age levels. Memory for digits is a good test item because the performance returns to a characteristic stable level in spite of temporary gains during intensive practice. Cutting at this age would be a poor test because slight practice produces an almost perfect performance. The only graded series used was the walking-boards of different widths. The reliable differences between performances on boards of different size suggest that these boards might be used for diagnosis of gross motor ability.

Improvement with practice and retention after practice are very significant problems in the training of children. Educationally, questions may well be asked, many of which will be answered by future experiments: At what stage of development can training or practice give the most economical results? There is probably an optimum time or times for training in any particular skill (as has been shown in the pecking of chicks). It is important to know when these times are and under what conditions specific practice is most effective. For example, it would appear that the specific practice in cutting was very economical, though possibly not all of it was necessary. By testing immediately or soon after practice, are we measuring all that is retained? Burtt's experiment (2) on training in Greek at an early age presents many problems which need experimental exploration. What spacing of practice will keep performances at a level of achievement? In most of the performances in the present experiment the degree of skill attained by special practice had been maintained or improved by the time of the first retests two or three weeks later. These retests, in fact, look very much like a continuation of the learning curve itself. If all of the retests had been placed at three-week intervals, the form of the subsequent curve might have been quite different. It is interesting to speculate, too, regarding the comparisons which could have been made if the early-practice twin had continued special practice through the delayed practice period. It is a problem for future investigation to continue the practice of a first group of children while second and third groups start at respectively later dates.

Other practical questions are pertinent. Degrees of guidance during practice may well be differentiated in their influence on learning and retention.[10] As Goodenough and Brian (16) have shown, thoroughness of coaching influences level of performance in ring-tossing of preschool children. Their data, however, offer no retests at subsequent intervals which might throw light on the relation of training to retention; this point is the crucial one for education. Closely related to the question of kind of practice is that of *amount* of practice given. Thus far, experiments which have dealt with the effect of practice on developing abilities have varied from 1 to 7 days' practice per week and from 5 weeks to 21 months for the total period of intensive practice. Such deviations constitute an advantage if varying conditions are to be studied. They make it difficult to arrive at average effects.

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[10] A series of studies dealing with the significance of different degrees of guidance in the maze behavior of rats and human subjects have been summarized by Carr (3).

From the range and number of factors involved in the effect of specific practice on the performances of children, it is clear that the problem is very complex. The interaction of environmental and maturational factors in this type of experiment make impossible the assignment of definite value to the underlying maturational mechanism. Undoubtedly, that mechanism is operating; but it is doubtful whether an experiment along the present lines could be definitive or crucial. The attack on the problem gives evidence which is of more significance educationally and clinically.

Disagreement or agreement of studies on various functions at the different age levels are equally valuable for the light they throw on the total problem. In a recent criticism of the maturation hypothesis Witty and Lehman (36), commenting upon the studies of children, feel that no defensible premise regarding heredity and environment is possible "since the reports do not agree precisely." It is this very fact of non-agreement under slightly varying experimental conditions that familiarizes us with the complex factors of variation. No one study can hope to do more than add evidence which will eventually be absorbed into a synthesis though no such synthesis is possible today. It is hoped that the study which has just been reported will contribute to a better understanding and analysis of the factors which underlie the acquisition of skill in the young child.

VII

SUMMARY

1. Monozygotic Twins *T* and *C*, previously used in experiments by Gesell and Thompson and by Strayer, were 54-66 months of age during the experiment. On preliminary tests, they were found to be highly similar on a variety of tests of intelligence, vocabulary, drawing, memory, handedness, footedness, and motor speed; they displayed differences on perseveration tests.

2. The twins were well matched initially on motor tests of cutting, ring-tossing, and on walking-boards 2, 4, and 6 centimeters in width and on tests of digit-memory and object-memory. Each twin served both as practice and control subject throughout the experiment. For each memory and motor item there was an initial test, then one twin was practiced (early practice) while the other served as control; both were retested, then the second twin was practiced (delayed practice) while the previously practiced twin served as control. Each practice period was 8 weeks in length with 3 practice periods per week. Delayed practice began 3 months after the early practice. Both twins were retested after delayed practice and again 3 and 6 months later.

3. Delayed practice resulted in a greater gain for the delayed-practice twin on digit-memory, object-memory, ring-toss, and errors on walking-boards 2 and 4 cm. in width. It resulted in similarity of scores on cutting corners and walking-board 6, both of which

involved performances near maximum. In deviations in cutting, an individual technique produced a consistent difference so that the delayed twin never equalled the score of her earlier-practiced sister.

4. Loss with cessation of early practice occurred in digit-memory and ring-toss with an ambiguous result in object-memory; performance on certain of the walking-boards continued to show a slight gain. After delayed practice, loss was evident in object-memory, digit-memory, ring-toss, and errors on board 2. Cutting showed no loss after either practice period.

5. Three and six months after practice, the performance of the twins on all tests were as similar to each other as at the beginning of the experiment.

6. The greater gain of the delayed twin was considered in relation to individual differences, additional spaced practice, better adjustment to experimental conditions, and maturation. The fact that the performances of both twins returned to the same level despite their different attainments with practice pointed to the importance of the general developmental factors. In cutting, where only a limited amount of practice was necessary to bring it to a point near the maximum with no loss in skill at any subsequent time, it appeared that the underlying factors were probably developed. The bearing of the results on educational theory and method was discussed.

7. Certain general principles concerning the effect of specific practice on the performances of children are suggested. For example, substantial gains by the control without practice are accompanied by relatively stable and permanent gains by the practice child; the reverse also seems to hold true.

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L'EFFET DE L'EXERCICE FAIT DE BONNE HEURE ET DE L'EXERCICE RETARDÉ SUR LE RENDEMENT DE MÉMOIRE ET LE RENDEMENT MOTEUR ÉTUDIÉ SELON LA MÉTHODE DE CONTRÔLE DE DEUX JUMELLES

(Résumé)

1. Les jumelles monozygotes *T* et *C* déjà employées dans des expériences par Gesell et Thompson et par Strayer ont eu 54-66 mois pendant l'expérience. Sur les tests préliminaires, on les a trouvées très semblables.

2. Les jumelles ont été bien égales initialement sur les tests moteurs consistant à couper, à jeter des cercles, et à marcher sur des planches de 2, de 4, et de 6 centimètres de large et sur les tests de mémoire de chiffres et de mémoire d'objets. Chaque jumelle a servi et comme sujet d'exercice et comme sujet de contrôle dans toute l'expérience. Pour chaque point de mémoire et point moteur, il y a eu un test initial), ensuite on a donné de l'exercice à l'une des jumelles (l'exercice fait de bonne heure) pendant que l'autre a servi comme contrôle; on a testé deux de nouveau, ensuite la seconde jumelle a fait de l'exercice (l'exercice retardé) pendant que la première, qui a déjà fait de l'exercice, a servi comme contrôle. Chaque période d'exercice a duré huit semaines avec trois périodes d'exercice par semaine. L'exercice retardé a commencé trois mois après l'exercise fait de bonne heure. On a testé de nouveau les deux jumelles après l'exercice retardé et encore trois at six mois plus tard.

3. L'exercice retardé a montré un plus grand rendement chez la jumelle qui a fait l'exercice retardé pour le test de mémoire de chiffres, celui de mémoire d'objets, celui de jeter les cercles, et celui de marcher sur des planches de 2 et de 4 cm. de large. Il a montré des résultats semblables pour le test de couper les coins et celui de marcher sur la planche de 6 cm. de large, dont les deux ont compris des rendements à peu près maxima. Dans les déviations de couper, une technique individuelle a produit une différence constante de sorte que la jumelle qui a fait l'exercice retardé n'a jamais égalé le résultat de sa soeur qui a fait l'exercice de bonne heure.

4. Une perte avec la cessation de l'exercice de bonne heure s'est montré dans le test de mémoire de chiffres et dans celui de jeter les cercles, avec un résultat ambigu pour celui de mémoire d'objets; certains tests sur les planches ont continué à montrer un rendement un peu plus grand. Après l'exercice retardé, une perte s'est montré dans le test de mémoire d'objets, celui de mémoire de chiffres, celui de jeter les cercles, et les erreurs de la planche large de 2 cm. *Le test de couper n'a montré aucune perte après* ni l'une ni l'autre période de l'exercice.

5. Trois et six mois après l'exercice, les rendements des jumelles sur tous les tests ont été aussi semblable l'un à l'autre qu'au commencement de l'expérience.

6. Le plus grand rendement de la jumelle qui a fait l'exercice retardé a été considéré dans son rapport aux différences individuelles, au nouvel exercice espacé, à la meilleure adaptation aux conditions expérimentales, et à la maturation. Quoique la maturation ait probablement opéré, il a été impossible, sur la base des données, d'y donner une partie spécifique dans le plus grand rendement.

7. On suggère certains principes généraux sur l'effet de l'exercice spécifique sur les rendements des enfants. Par exemple, les progrès importants faits par le contrôle sans exercice sont accompagnés de progrès relativement stables et permanents par l'enfant qui a fait l'exercice; le contraire semble aussi être vrai.

HILGARD

DIE EINWIRKUNG DER FRÜHEN UND DER VERZÖGERTEN ÜBUNG AUF DAS GEDÄCHTNIS UND AUF MOTORISCHE TÄTIGKEITEN — UNTERSUCHUNG MIT DER METHODE DER ZWILLINGSKONTROLLE

(Referat)

1. Die Versuchspersonen, die monozygotischen Zwillinge *T* und *C*, waren schon früher in Experimenten von Gesell und Thompson und von Strayer als Versuchspersonen verwendet worden. Ihr Alter betrug während der gegenwärtigen Untersuchung 54 bis 66 Monate. An Vorprüfungen hatten sie sich als einander höchst ähnlich erwiesen.

2. Anfänglich stimmten die Leistungen der Zwillinge an motorischen Prüfungen gut mit einander überein. (Diese Prüfungen betrugen Schneiden, das Werfen von Ringen [ring-toss], und das Belaufen von Brettern [walking-boards] von respektiv 2, 4, und 6 Cm. Breite.) Auch in Bezug auf ihre Leistungen an Prüfungen des Zahlengedächtnisses [digit-memory] und des Gedächtnisses für Gegenstände glichen die Zwillinge einander stark. Jede der Zwillinge diente während der ganzen Untersuchung sowohl als Versuchsperson wie als Kontrollperson. Für jeden Gegenstand der Untersuchung des Gedächtnisses und der motorischen Tätigkeit gab es zuerst

eine Anfangsprüfung. Dann wurde eine der Zwillinge eingeübt (frühe Einübung), während die andere als Kontrollperson diente. Beide wurden wieder geprüft. Dan wurde die zweite eingeübt (verzögerte Einübung) während das vorher eingeübte Kind als Kontrollperson diente. Jede Einübungsperiode zog sich über acht Wochen hin. Es gab drei Einübungsperioden per Woche. Die verzögerte Einübung begann drei Monaten nach der frühen Einübung. Beide Zwillinge wurden nach der verzögerten Einübung wieder geprüft, und drei und dann sechs Monaten später nochmals geprüft.

3. *Die verzögerte Einübung verursachte bei dem "zurückgehaltenen"* [delayed] Zwilling einen grösseren Gewinn in Bezug auf Gedächtnis für Zahlen, Gedächtnis für Gegenstände, Ringwerfen, und Fehlern bei dem Belaufen von Brettern von 2 und 4 Cm. Breite. Bei dem Abschneiden von Ecken und in Bezug auf das Gehbrett 6 (also bei Tätigkeiten, die fast vollkommen beherrscht wurden) bewirkte die verzögerte Einwirkung Ähnlichkeit der von den beiden Zwillingen erzielten Zahlen [similarity of scores]. In Bezug auf Abweichungen bei dem Schneiden von Ecken verursachte ein individuelles Verfahren einer der Zwillinge einen beständigen Unterschied solcher Art, dass das 'zurückgehaltene" Zwillingskind nie eine so hohe Zahl erhielt, wie dessen früher eingeübte Schwester.

4. Nach Einstellung der frühen Einübung fand in Bezug auf das Gedächtnis für Zahlen und das Werfen von Ringen eine Verlust statt. In Bezug auf das Gedächtnis für Gegenstände erwies sich das Resultat als zweideutig. Bei einigen Gehbrettprüfungen zeigte sich fortwährend eine kleine Besserung. Nach verzögerter Einübung zeigten sich Verluste in Bezug auf das Gedächtnis für Gegenstände, das Zahlengedächtnis, und *die auf dem zweiten Gehbrett begangenen Fehler. In Bezug auf das* Schneiden fand weder nach der frühen noch nach der verzögerten Einübung eine Verlust statt.

5. Drei und sechs Monaten nach der Einübung waren die Leistungen der Zwillinge an allen Prüfungen einander gerade so ähnlich, wie sie es vor Anfang der Untersuchung gewesen waren.

6. Das grössere Gewinn bei dem "zurückgehaltenen" Zwillingskind wird in Bezug auf individuelle Unterschiede, hinzugefügte gesonderte [spaced] Einübung, verbesserte Anpassung an experimentelle Bedingungen, und Reifung [maturation] besprochen. Obwohl die Reifung warscheinlich von Einfluss war, war es, auf basis der Befunde, unmöglich, ihr einen spezifischen Anteil an dem Gewinn zuzuteilen.

7. Es werden in Bezug auf die Einwirkung der spezifischen Einübung auf die Leistungen von Kindern gewisse allgemeine Prinzipien vorgeschlagen. Es gehen zum Beispiel bestimmte Gewinne bei dem Kontrollkind ohne Einübung mit relativ beständigen und dauerhaften Gewinnen des Versuchskindes einher. Das Gegenteil scheint ebenfalls gültig zu sein.

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